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Applicant HULBERT, Anthony, Peter et al	

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(71) Applicant *(for all designated States except US)*: **ROKE MANOR RESEARCH LIMITED** [GB/GB]; Roke Manor, Old Salisbury Lane, Romsey, Hampshire SO51 0ZN (GB).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **HULBERT, Anthony, Peter** [GB/GB]; 48 Wilton Crescent, Shirley, Southampton, Hampshire SO15 7QH (GB). **WALES, Stephen, William** [GB/GB]; 19 Sovereign Court, 5 Winn Road, Southampton, Hampshire SO17 1EH (GB). **HALLS, Geoffrey, Alan** [GB/GB]; 7 Bramble Drive, Romsey, Hampshire SO51 7RJ (GB). **KOEHN, Reinhard, Walter** [DE/DE]; Homburger Strasse 21, D-14197 Berlin (DE).

(74) Agents: **ALLEN, Derek** et al.; Intellectual Property Department, Siemens Shared Services Limited, Siemens House, Oldbury, Bracknell, Berkshire RG12 8FZ (GB).

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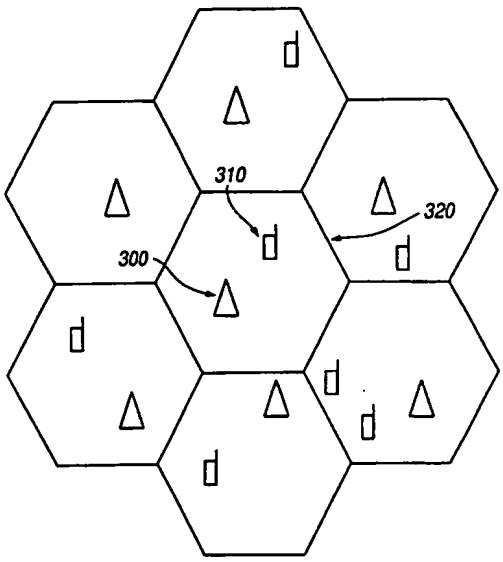

(57) Abstract: Described herein is a method of providing synchronisation between a plurality of base stations (300) in a telecommunications system which comprises providing a random access channel in each cell (320). A local base station (300) uses the random access channel in the local cell to transmit a synchronisation signal to neighbouring base stations. For each base station, the time differences between received synchronisation signals from neighbouring base stations and the local synchronisation signal are calculated. Each set of time differences is either used to autonomously synchronise the local base station or is centralised in a radio network controller and a set of corrections distributed from the RNC to the base stations.

WO 01/15340 A1

IMPROVEMENTS IN OR RELATING TO MOBILE TELECOMMUNICATIONS SYSTEMS

The present invention relates to improvements in or relating to mobile telecommunications systems and is more particularly concerned with synchronisation of base stations within a telecommunications system.

The UMTS terrestrial radio access time division duplex (UTRA TDD) mode is based on a combination of code division multiple access (CDMA) and hybrid time division multiple access (TDMA). UMTS is an acronym for universal mobile telecommunication system as will be understood by persons skilled in the art.

Reliable operation in the UTRA TDD mode, incorporating the combined TD-CDMA multiple access scheme, requires synchronisation between base stations within a compliant telecommunications system. Moreover the mode also requires the provision of position information for the mobile stations affiliated to each base station. Synchronisation between base stations is also desirable in order to maximise system capacity. To these ends, the synchronisation of base stations must be achieved at the levels of time slots, frames and multi-frames, where a multi-frame is a repeating cycle of a number of frames.

One known mechanism for synchronising the base stations is to equip each base station with a global positioning system (GPS) receiver. However, this is not always appropriate or even possible; for example, an area of deployment may be shadowed from the GPS constellation of satellites by tall buildings. For this and other reasons, alternative mechanisms for synchronising the base stations are required.

In an alternative mechanism, the base stations are synchronised over the backhaul network; the network which enables base stations to switch mobile communications into public telephone networks or the internet. However, if this mechanism is implemented according to a packet protocol (for example, internet protocol (IP) or asynchronous transfer mode (ATM)), then synchronisation will only be possible to a coarse accuracy.

It is therefore an object of the present invention to obviate or at least mitigate the problems of synchronisation of base stations.

In accordance with a first aspect of the present invention, there is provided a method of providing synchronisation between a plurality of base stations in a telecommunications system, for each base station there is a telecommunications cell within which there is at least one mobile station and for each base station the method comprises the steps of: providing at least one channel for usage in the telecommunications cell; a transmission step, wherein said at least one channel is utilised for transmission of a synchronisation signal, the transmission being from a first base station to those remaining base stations within the telecommunications system which are within transmission range; and a first calculation step, in which a time difference between clock pulses from the first base station and clock pulses transmitted by other base stations within transmission range is calculated.

Preferably the method has the further steps: a reporting step, in which each of the plurality of base stations reports the time differences calculated in the time difference calculation step to a radio network controller; a second calculation step, wherein a synchronising adjustment corresponding to each base station is calculated from the reported time differences; and an adjusting step, wherein each base station is individually

sent the corresponding synchronising adjustment and the clock of the base station concerned is adjusted accordingly.

Advantageously, each of the plurality of base stations can act autonomously on the basis of information received from the available remaining base stations to adjust the clock timing of that base station.

The channel utilised for transmission of the synchronisation signal is preferably a random access channel (RACH) which is transmitted at a frequency within a band of frequencies that is provided for communications with mobile stations. The random access channel advantageously comprises a single time slot per TDMA frame. More preferably, the RACH is allocated to transmissions from mobile stations to initiate communications. Preferably, communications are initiated by requesting a resource unit (time slot and CDMA code combination) for uplink usage.

The method preferably further comprises a scheduling step in which the utilisation of each RACH time slot for base station synchronisation is allocated according to a schedule.

More preferably, the method further comprises a silencing step in which a second channel is used by the base station to silence mobile station communications in the RACH time slots to allow the transmission of synchronisation transmissions to other base stations. This second channel is most preferably the broadcast control channel (BCCH).

In accordance with a second aspect of the present invention, there is provided a method of locating a mobile station within a telecommunications cell forming part of a telecommunications system, the telecommunications cell comprising a base station and at least one mobile station, the method comprising the steps of: determining the location of at least three base stations; scheduling synchronisation measurements for

each of the base stations utilising a random access channel; transmitting a signal from the mobile station; receiving the transmitted signal at each of the three base stations; comparing the received signals with timing signals in each of the base stations; and using the comparison at each base station to determine the location of the mobile station.

For a better understanding of the present invention, reference will now be made, by way of example only, to the accompanying drawings in which:-

Figure 1 shows a schematic diagram of the UTRA TDD mode.

Figure 2 shows a schematic diagram of one TDMA frame.

Figure 3 shows a schematic diagram of a network of telecommunication cells.

Figure 4 shows a schematic diagram of the time differences between the signals from base stations.

In Figure 1, the UTRA TDD mode is illustrated. Information is transmitted in bursts at a certain combination of frequency, time (within a frame 102), and coding. Frames 102 are divided into time slots 104 and each time slot is just long enough for a single burst of information. Transmission of information is multiplexed through the use of orthogonal codes (CDMA). The information transmitted within a particular time slot is divided according to these codes: as a result, each burst contains a plurality of independent time slot and code combinations, called resource units 106.

The UTRA TDD mode uses a scheme called Time Division – Code Division Multiple Access (TD-CDMA). This scheme provides for a random access channel (RACH) which is a single time slot 104 per TDMA

frame 102. The RACH is allocated to transmissions from mobile stations to initiate communications, usually by requesting a resource unit 106 for uplink usage. The RACHcan be utilised for both inter base station synchronisation and for mobile station position location.

A TDMA frame is illustrated in Figure 2. As will be apparent, each TDMA frame 200 contains a plurality of time slots 210; fifteen time slots in TDD mode, as shown.

Figure 3 depicts a typical cellular deployment. Each base station 300 has an associated cell 320. The range between neighbouring base stations 300 is roughly double the range from any base station to a mobile station 310 at its cell boundary. In an urban deployment, this typically leads to a path loss which is of the order of 12dB greater to the neighbouring base station 300 than to the cell-edge mobile station 310. On the one hand, the base station 300 would have a height gain advantage over a mobile station 310 at the same location. On the other hand the base station antennas are typically constructed with a 'down tilt' intended to reduce inter cell interference. These opposing effects are of similar magnitude and will tend to cancel, making the 12dB figure a reasonable estimate for the increase in path loss.

Figure 4 shows how the time differences, $d_{i,j}$, between the local base station 'a' and the neighbouring base stations 'b' and 'c' are derived from the synchronisation signals. The shaded time slot represents the RACH which can carry synchronisation signals. The upper boxed area represents the time differences at base 'a': from top to bottom the lines represent: a) the base station's own signal; b) the delayed signal from base station 'b'; and c) the delayed signal from base station 'c'. Similarly the lower boxed area represents the time differences at base 'b'. There is no

line corresponding to base station 'c' – as would be the case when 'c' was out of range of the signal from 'b'.

In the first embodiment of the present invention, there is provided a base station which conforms to the UTRA TDD mode. The base station uses the RACH to synchronise with other base stations which are within transmission range. The base station is arranged to 'steal' the RACH time slot for transmissions to other base stations at suitable times. In this discussion it is assumed that the same time slot will be used for RACH operation in all cells; whilst this assumption is advantageous, it is not essential to the operation of this invention. The times at which a base station should steal a RACH time slot can be determined according to the following criteria:

Firstly, neighbouring base stations must not steal the RACH time slot in the same frame.

Secondly, RACH time slots must be stolen frequently enough to maintain overall base station network synchronisation to the required accuracy.

Lastly, schedules for RACH time slot stealing may be determined either centrally by a radio network controller (RNC) or according to sequence generators resident in the base stations. In the latter case, the sequence generators are arranged in such a way that RACH stealing schedules do not coincide in neighbouring cells. If the RNC is used, it can establish schedules according to this criterion. The schedules may be at regular, pseudo random or constrained random intervals.

When the base station has a schedule assigned for RACH stealing in the near future, at a suitable time it makes a broadcast transmission (preferably on its broadcast control channel, BCCH) to all mobile stations affiliated to the base station, to instruct these mobile stations that the

RACH will be unavailable for mobile station transmissions in the forthcoming scheduled stolen RACH time slot. This will clear the stolen RACH time slot for inter cell synchronisation usage.

Arranging for the stealing base station to silence mobile stations affiliated to the stealing base station when the RACH is stolen, will prevent unnecessary collisions on the RACH channel. However, as described so far, the neighbouring base stations will not silence *their* respective affiliated mobile stations from making RACH transmissions. These RACH transmissions will be power controlled and it should be possible for the neighbouring base stations to receive the transmission from the base station stealing the RACH timeslot and to receive any RACH transmissions from their own affiliated mobile stations. However, in the case where stolen RACH timeslots are scheduled by the RNC, it is optionally possible to arrange for the neighbouring base stations to silence RACH transmissions from their mobile stations using the same procedure as described for the RACH time slot stealing.

In this way the interference to the synchronisation transmission can be substantially removed, except from distant stations. If this option is not employed then interference to the reception of synchronisation transmission in the RACH timeslot may prevent its reception. However, given the statistics of RACH traffic, a high proportion of such measurements should be received.

In the second embodiment of the present invention, an alternative approach to 'stealing' RACH slots for synchronisation is taken. In this approach, RACH slots are arranged throughout the network of base stations to be allocated to synchronisation at regular fixed intervals. During these allocated RACH slots, none of the mobile stations make RACH transmissions, and it is unnecessary to instruct the mobile stations

not to make the RACH transmissions since they are capable of determining such times for themselves. However, the base stations do transmit a simple binary signal periodically to indicate that this mode of operation applies: such a transmission would not be necessary in a network where all base stations had associated GPS receivers. In consequence, during the allocated RACH time slots all base stations are either listening for synchronisation transmissions or making them. The subset of base stations making synchronisation transmissions changes from one selected RACH time slot to the next. It is necessary to ensure that the spread of transmissions is such that only one dominant synchronisation signal is received at any given base station in any given selected RACH time slot. The planning of these subsets can be performed either manually or automatically according to scheme similar to dynamic channel assignment (DCA).

Within UTRA TDD, bursts are transmitted within time slots and each burst is sub-divided into 2560 chips which are zoned into two data fields, one midamble field and a guard period. The midamble field contains training sequences. Because the base stations are static and have accurate frequency references, it is possible to perform correlation across the entire time slot. Correlation makes use of training sequences so the synchronisation burst, with the exception of the guard period, is arranged to have no data fields and effectively becomes all midamble. Whole time slot correlation affords a processing gain of about 34dB. This high processing gain serves to compensate for the increased path loss to the neighbouring cells.

Assuming that every base station sends and receives synchronisation bursts to and from its neighbouring base stations, all of the information necessary for the network wide synchronisation can be

aggregated. This can be used in one of two distinct ways, either distributed or centralised.

The first and second embodiments of the invention detail methods of gaining access to RACH timeslots. Either embodiment can be implemented according to the distributed or centralised approaches.

In the distributed approach, every base station acts autonomously on the basis of the information it has received to adjust its clock timing in such a way that, given that all other base stations operate similarly, they will come into synchronisation.

In the centralised approach, all base stations report their results to the RNC which then computes a set of adjustments and signals these adjustments individually to the relevant base stations. Essentially, each base station measures the timing of each received synchronisation burst relative to its own timing. This can be viewed as the timing of the received burst relative to the time at which it would make its transmission. Each base station is provided with a matched filter, matched to the synchronisation code. When a burst is received, there will usually be several discrete paths. The earliest significant path will be taken to provide the timing since this is most likely to correspond to the line of sight path if there is one. The following discussion relates to the centralised synchronisation procedure, following coarse level synchronisation.

Suppose we have a deployment of N base stations. Let the variable $L(i,j) = L(j,i)$ indicate those base stations which are able to hear each other's synchronisation transmissions. If base station i can hear base station j's transmission and base station j can hear base station i's transmission then $L(i,j) = L(j,i) = 1$. Otherwise $L(i,j) = L(j,i) = 0$. Note that $L(i,i) = 0$ for all i. All relative timings are aggregated at the RNC. If

base station i hears base station j's transmission with delay $d_{i,j}$ and base station j hears base station i's transmission with delay $d_{j,i}$, then the RNC computes the time differences as

$$\delta_{i,j} = \frac{d_{i,j} - d_{j,i}}{2}$$

and

$$\delta_{j,i} = \frac{d_{j,i} - d_{i,j}}{2} = -\delta_{i,j}$$

Referring once more to Figure 4, it is plain that $L(a,b) = L(b,a) = 1$ and $L(a,c) = L(c,a) = 1$ but $L(b,c) = L(c,b) = 0$. Figure 4 also illustrates how the time differences, $d_{i,j}$, are derived. Thus $\delta_{i,j}$ is the time by which base station i's time is advanced with respect to the time of base station j and excludes any time delay due to intervening distance.

Suppose base station i will be retarded by a compensation amount C_i which is to be computed. Following such compensation, the new timing error between base stations i and j will be given by

$$\delta'_{i,j} = \delta_{i,j} - C_i + C_j$$

If all measurements were completely accurate and consistent, we could simply solve the equations to make $\delta'_{i,j} \equiv 0$ for all i and all j.

However, given measurement errors it is better to solve for a minimum sum square error, that is,

$$\sum_{i=1}^{N}\sum_{j=1}^{N} L(i,j)\,\delta'^{2}_{i,j}$$

should be minimised. Expanding this gives:-

$$\sum_{i=1}^{N}\sum_{j=1}^{N} L(i,j)\left\{\delta^2_{i,j} + C_i^2 + C_j^2 + 2\left(\delta_{i,j}.C_j - \delta_{i,j}.C_i - C_i.C_j\right)\right\}$$

Let $M(i) = \sum_{j=1}^{N} L(i,j)$ be the number of base stations whose synchronisation transmissions base station i can hear and who can also

hear base station i's synchronisation transmission. We can then express the sum square error as

$$2\sum_{i=1}^{N} M(i)C_i^2 + \sum_{i=1}^{N}\sum_{j=1}^{N} L(i,j)\delta_{i,j}^2 - 4\sum_{i=1}^{N} C_i \sum_{j=1}^{N} L(i,j)\delta_{i,j} - 2\sum_{i=1}^{2}\sum_{j=1}^{N} L(i,j)C_j$$

Now differentiate with respect to C_i and equate to zero. We obtain

$$4M(i)C_i - 4\sum_{j=1}^{N} L(i,j)\delta_{i,j} - 4\sum_{j=1}^{N} L(i,j)C_j = 0$$

Thus

$$M(i)C_i - \sum_{j=1}^{N} L(i,j)C_j = \sum_{j=1}^{N} L(i,j)\delta_{i,j}$$

We can express this in matrix notation as

$$(\mathrm{diag}(\mathbf{M}) - \mathbf{L})\mathbf{C} = \mathbf{D}$$

where $\mathrm{diag}(\mathbf{M})$ is the diagonal matrix with elements $M(i)$, $i \in \{1...N\}$ along the diagonal,

L is the matrix with elements $L(i,j)$,

C is the vector with elements C_i, and

D is a vector with elements

$$D_i = \sum_{j=1}^{N} L(i,j)\delta_{i,j} = \sum_{j=1}^{M(i)} \delta_{i,S_j(i)}$$

where $S_j(i)$, $j \in \{1...M(i)\}$ is the set of indices of base stations to and from which base station i can send and receive synchronisation transmissions respectively.

Let $\mathbf{A} = (\mathrm{diag}(\mathbf{M}) - \mathbf{L})$

This matrix is singular, i.e. has no inverse. This reflects the fact that any common value can be added to all compensation values, C_i, without affecting the sum square error. A reasonable constraint to apply to the compensation values is that their sum should be zero so as to minimise the overall drift. Thus, we have an additional equation:-

$$\sum_{i=1}^{N} C_i = 0$$

This can be reflected in the matrix equation by adding a row of ones to any of the rows in **A** to form **A'**.

We can now solve the equation to obtain the compensation values. However, we can note that **A** (and therefore **A'**) does not change very rapidly, if at all, since it is a function only of the base station connectivity. Thus, it may be more efficient to compute the inverse of **A'** which need only be updated infrequently. We thus obtain:-

$$\mathbf{C} = (\mathbf{A'})^{-1} \cdot \mathbf{D}$$

Having these compensation values, C_i, each base station in the telecommunications system can be synchronised with every other base station. In addition to fulfilling the requirements of UTRA TDD mode, synchronisation is important in locating mobile stations.

A mobile station may need to be located within its cell, notably when the user makes an emergency call or simply in order to ensure a clean hand-over as the mobile station crosses into a neighbouring cell. Position measurements can be performed on the basis of delay measurements. A minimum of three base stations must be involved in the measurements in order to obtain an unambiguous location. This is because two dimensions of space plus time must be determined. In order for such positioning to be performed the base stations involved must either be synchronised or at least know their mutual time difference to a high accuracy. The periodic updating described earlier may not provide accurate enough synchronisation for position location.

According to the third embodiment of the present invention, requesting the location of a mobile station initiates a set of synchronisation

measurements between the base stations involved. Before this can be done, it must be determined which base stations are involved. The simplest, although least efficient, approach to determining this set of measurements is to assume that the base station to which the mobile station is affiliated and the list of base stations neighbouring that base station are all involved.

A more efficient approach would be to arrange for the mobile station to monitor the signal strength of the BCCH channels of the neighbouring base stations and report the addresses of the two (or more) base stations providing the strongest signals. Alternatively, the mobile stations can simply report the actual BCCH signal strength and the receiving base station or the RNC can determine the base stations to be involved. The BCCH signal strength can be measured by correlating against the appropriate training sequences. It will be understood that these measurements will be performed anyway to support the hand-over decision process.

Once the set of base stations involved has been determined, the schedules for synchronisation measurements can be established for each base station. The procedure is then identical to that described previously for normal synchronisation. The mobile station is also instructed to make, at a suitable time, a transmission at full power on the RACH using, preferably, the same burst structure as defined earlier for inter base station transmissions. The time for this transmission should be close to the transmission times for the inter base station synchronisation transmission in order to minimise the effect of clock drift. However, the mobile station transmission may be before, interspersed with or after the inter base station synchronisation transmissions. In a preferred implementation, the RNC will select the schedule for the mobile station to make its transmission.

This will be signalled to the mobile station on a suitable signalling channel by the base station to which it is affiliated. Other means of scheduling are not precluded. The RNC will also instruct the base stations involved to signal, preferably in their BCCH channel, to their affiliated mobile stations that random access transmission is unavailable in that particular RACH time slot.

Alternatively, this RNC instruction may be restricted to just the base station to which the mobile station is affiliated. The rationale for this restriction is that the mobile station is transmitting at full power and so can easily reach the base station at the centre of its own cell with enough power to make RACH reception possible. However, the range to the other base stations will typically be greater than the range from any mobile station attempting to transmit in a RACH within the cells of those other base stations. Since these cells will use power control, it is possible for the processing gain between the various training sequences to facilitate simultaneous reception.

The three (or more) base stations will each receive the signal from the mobile station and compare the reception time with their own timing. Given that the positions of the base stations will be known, this will provide all of the information needed to locate the mobile station.

Following any of the various transmissions required to support positioning, it may be discovered that either inter base station synchronisation transmissions or the transmission from the mobile station have not been received adequately. The RNC can schedule repeat transmissions as necessary, either to facilitate computation of the position or to improve its accuracy.

So far the discussion of synchronisation has covered only fine synchronisation after coarse synchronisation has already been achieved.

With an RNC in control, initial coarse synchronisation can be achieved in a straightforward manner. When a network is commissioned the base stations may be activated in sequence either by manual intervention or under control of the RNC. The first base station to be activated becomes the temporary timing master and makes periodic synchronisation burst transmissions in its RACH channel. Other base stations, activated later are only allowed to transmit after they have received a synchronisation burst. In this way the network will become synchronised globally. If an individual base station requires re-synchronisation, following a failure and repair, for example, again that base station is not allowed to transmit until it has received a RACH synchronisation burst from at least one other base station. It may then make its own RACH burst transmission, after making a coarse update to its timing from the initial burst.

The above achieves slot and frame synchronisation since the RACH slot is in a fixed position within the frame. Multi-frame synchronisation can be achieved by a number of means. The simplest and preferred method is to make the RACH slot which is 'stolen' for synchronisation always be contained in the first frame or any fixed arbitrary numbered frame within a multi-frame.

None of the above description precludes the incorporation of base stations equipped with a GPS receiver. In this case, the compensation values, C_i, for those base stations are set equal to zero and the constraint that the sum of compensation values equals zero is removed. In this way, the synchronisation scheme will cause all of the base stations involved to become synchronised either directly or indirectly to GPS.

CLAIMS:

1. A method of providing synchronisation between a plurality of base stations in a telecommunications system, the telecommunications system comprising a plurality of cells, each of the plurality of cells having one of the plurality of base stations and at least one mobile station, the method comprises the steps of:

a) providing at least one channel for usage in the plurality of cells;

b) transmitting a synchronisation signal in a given one of the at least one channel, the transmission being from a first base station to those remaining base stations within the telecommunications system which are within transmission range; and

c) calculating a time difference between clock pulses from the first base station and clock pulses transmitted by other base stations within transmission range.

2. A method according to Claim 1, having the further steps of:

d) for each of the plurality of base stations, reporting the time differences calculated in step c) to a radio network controller;

e) calculating a synchronising adjustment corresponding to each base station is calculated from the reported time differences;

f) informing each base station individually of the corresponding synchronising adjustment calculated in step e); and

g) adjusting the clock pulses of each base station according to the corresponding synchronising adjustment.

3. A method according to Claim 1, having the further step of:

h) the first base station acting autonomously on the time differences calculated in step c) by adjusting the clock pulses of the first base station to minimise the time differences.

4. A method according to Claims 1, 2 or 3, wherein the given channel is a random access channel transmitted at a frequency within a band of frequencies that is provided for communications with mobile stations.

5. A method according to Claim 4, wherein the random access channel comprises a time slot per TDMA frame.

6. A method according to Claim 5, wherein the random access channel is allocated to uplink transmissions in order to initiate communications.

7. A method according to Claim 6, wherein communications are initiated by requesting a resource unit for uplink usage.

8. A method according to Claims 5, 6 or 7, having the further step of:

i) allocating the utilisation of each random access channel time slot for base station synchronisation according to a schedule.

9. A method according to any one of Claims 5,6 or 7, having the further step of:

j) using a second one of said at least one channels to silence uplink communications in the random access channel time slots to allow the transmission of synchronisation transmissions from the first base station to other base stations.

10. A method according to Claim 9, wherein the second channel is the broadcast control channel.

11. A method according to any one Claims 4 to 10, wherein the random access channel time slot used is always contained in a fixed numbered frame within a plurality of multi-frames in order to synchronise the plurality of base stations over multi-frames.

12. A method of locating a mobile station within a telecommunications cell forming part of a telecommunications system, the telecommunications cell comprising a base station and at least one mobile station, the method comprising the steps of:

determining the location of at least three base stations;

scheduling synchronisation measurements for each of the base stations utilising a random access channel;

transmitting a signal from the mobile station;

receiving the transmitted signal at each of the three base stations;

comparing the received signals with timing signals in each of the base stations; and

using the comparison at each base station to determine the location of the mobile station.

13. A method of providing synchronisation between a plurality of base stations in a telecommunications system, the method substantially as hereinbefore described with reference to the accompanying drawings.

14. A method of locating a mobile station within a telecommunications cell forming part of a telecommunications system, substantially as hereinbefore described with reference to the accompanying drawings.

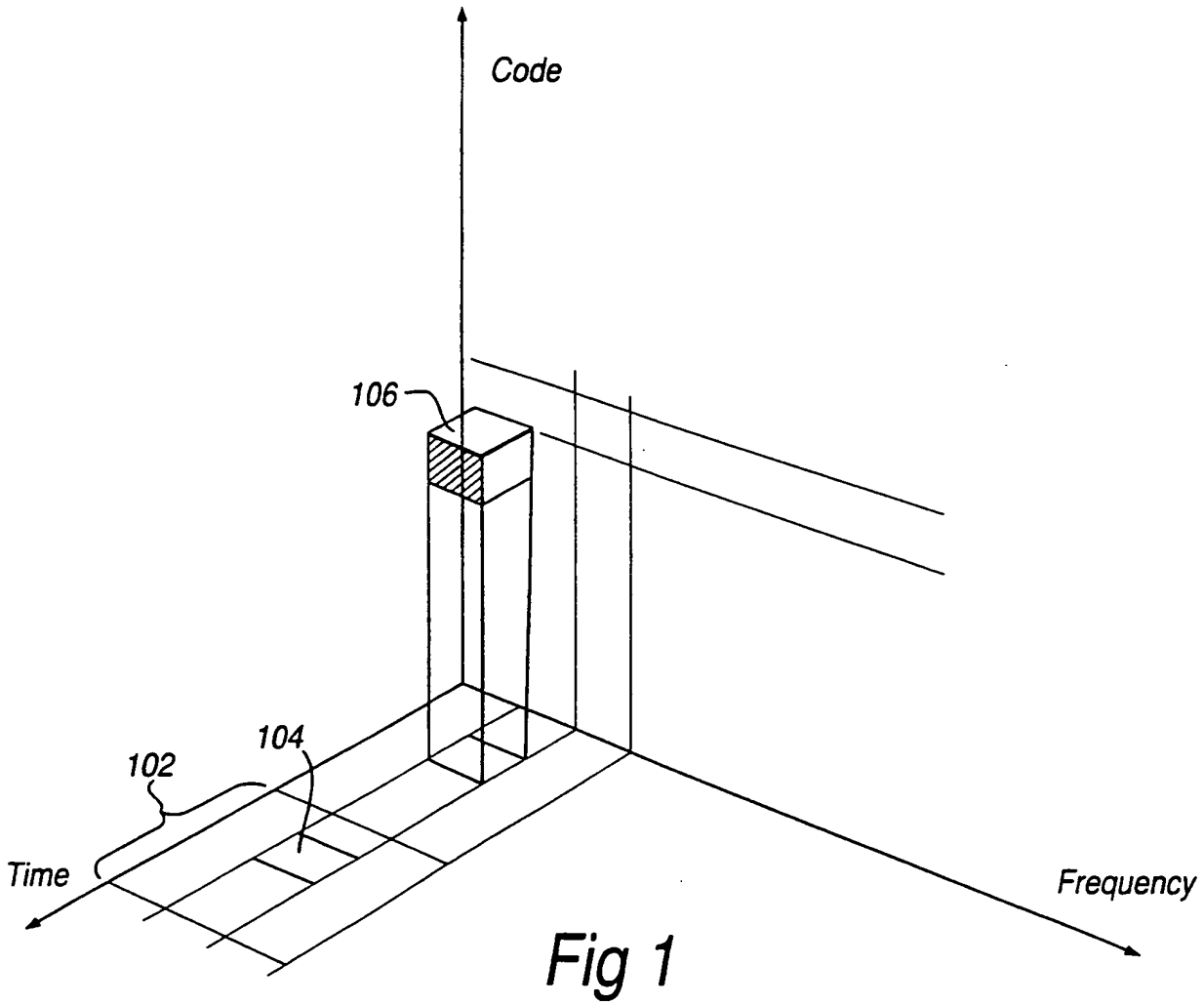

Fig 1

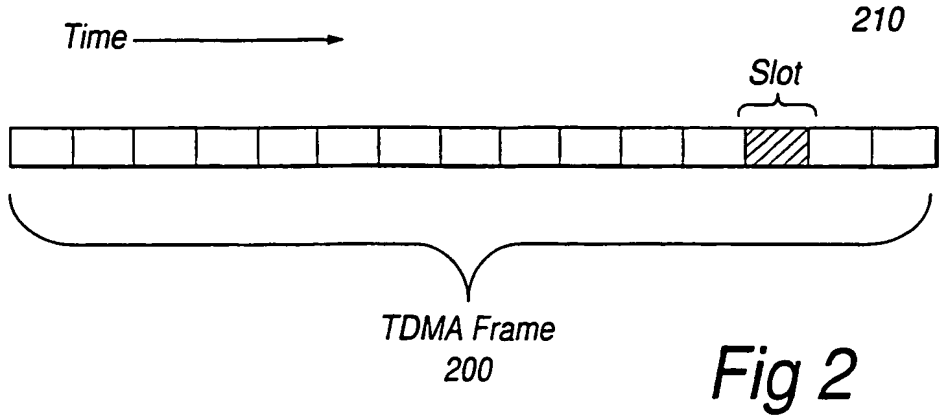

Fig 2

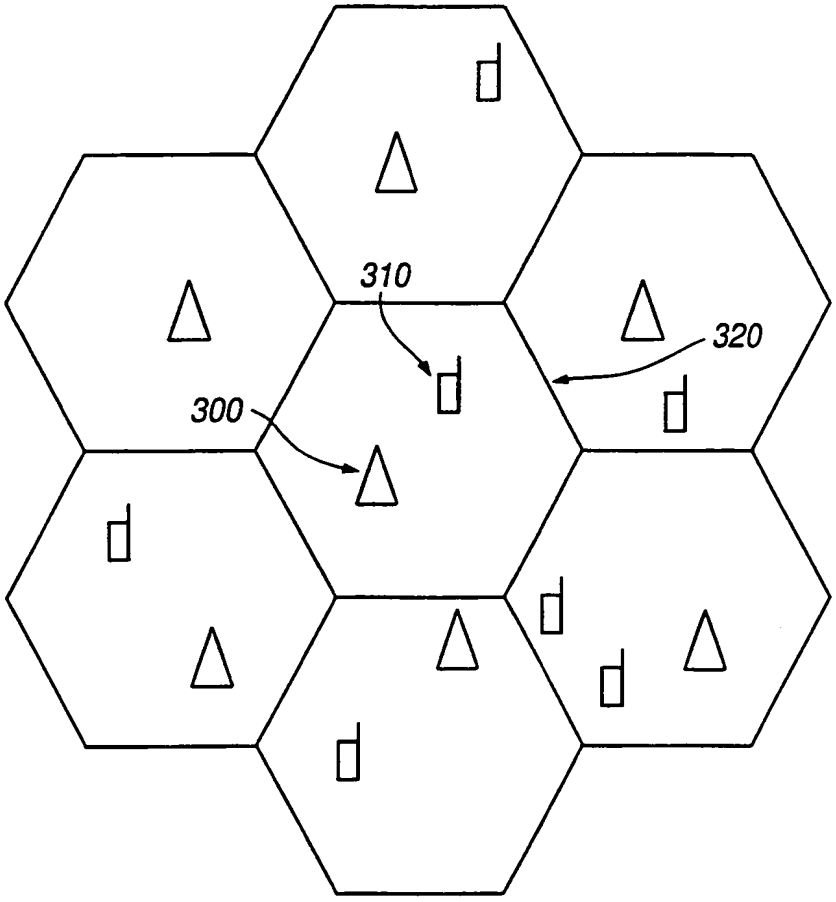

Fig 3

3/3

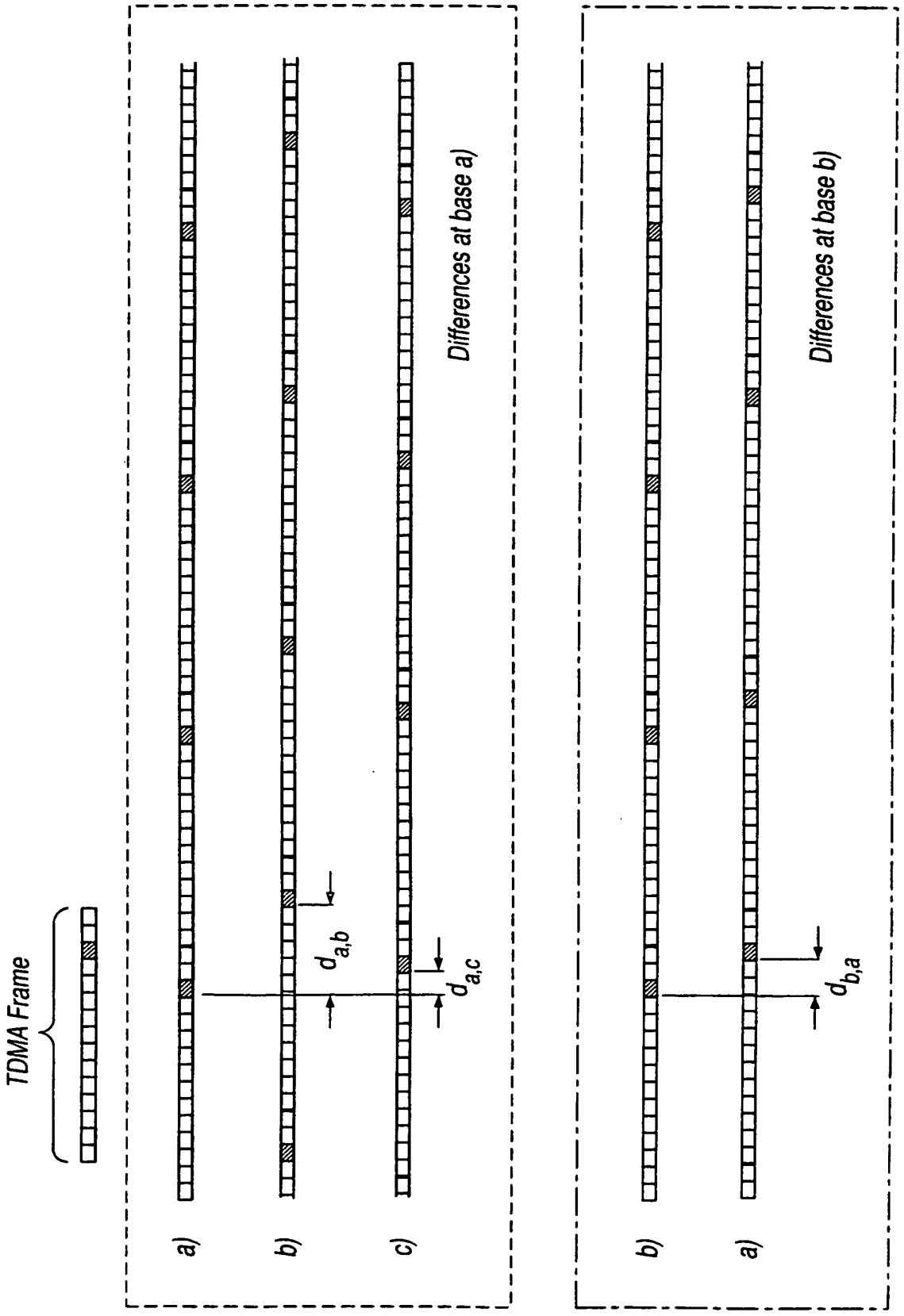
TDMA Frame
a)
b)
c)
$d_{a,b}$
$d_{a,c}$
Differences at base a)
b)
a)
$d_{b,a}$
Differences at base b)

Fig 4

INTERNATIONAL SEARCH REPORT

In[illegible]al Application No
PCT/GB 00/03111

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04B7/26 H04Q7/38

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04B H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, INSPEC, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	LAGRANGE X ET AL: "AUTONOMOUS INTER BASE STATION SYNCHRONISATION VIA A COMMON BROADCAST CONTROL CHANNEL" PROCEEDINGS OF THE VEHICULAR TECHNOLOGY CONFERENCE,US,NEW YORK, IEEE, vol. CONF. 44, 8 June 1994 (1994-06-08), pages 1050-1054, XP000496838 ISBN: 0-7803-1928-1 page 1050, left-hand column, line 1 -page 1052, right-hand column, line 10 ---	1,3,13, 14
X	EP 0 817 405 A (NIPPON ELECTRIC CO) 7 January 1998 (1998-01-07) column 1, line 1 -column 4, line 22 ---	1,3,13, 14
	-/--	

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 January 2001	12 02 2001

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Larcinese, A

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Int Application No
PCT/GB 00/03111

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
P,X	WO 99 57826 A (NOKIA TELECOMMUNICATIONS OY ;ESSER ALEX (FI); WESBY PHILIP (FI)) 11 November 1999 (1999-11-11) page 7, line 25 -page 16, line 34 figure 7 ---	1-4
X	WO 92 05672 A (TELEVERKET) 2 April 1992 (1992-04-02) page 3, line 27 -page 5, line 23 ---	12
X	EP 0 800 319 A (HEWLETT PACKARD CO) 8 October 1997 (1997-10-08) column 6, line 13 - line 39 column 7, line 15 -column 8, line 18 figure 3 -----	12

2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/GB 00/03111

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☒ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☒ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. Claims: 1-11,13,14

2. Claim : 12

INTERNATIONAL SEARCH REPORT

Information on patent family members

Int. Application No
PCT/GB 00/03111

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0817405 A	07-01-1998	JP 10094044 A	10-04-1998
		US 5936947 A	10-08-1999
WO 9957826 A	11-11-1999	AU 3826499 A	23-11-1999
WO 9205672 A	02-04-1992	SE 466376 B	03-02-1992
		DE 69119085 D	30-05-1996
		DE 69119085 T	22-08-1996
		EP 0551310 A	21-07-1993
		JP 6500902 T	27-01-1994
		SE 9002920 A	03-02-1992
EP 0800319 A	08-10-1997	US 6061565 A	09-05-2000

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CORRECTED VERSION

(19) World Intellectual Property Organization
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(51) International Patent Classification[7]: H04B 7/26, H04Q 7/38

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(22) International Filing Date: 11 August 2000 (11.08.2000)

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9919973.9	24 August 1999 (24.08.1999)	GB
0007143.1	24 March 2000 (24.03.2000)	GB

(71) Applicant *(for all designated States except US)*: **ROKE MANOR RESEARCH LIMITED** [GB/GB]; Roke Manor, Old Salisbury Lane, Romsey, Hampshire SO51 0ZN (GB).

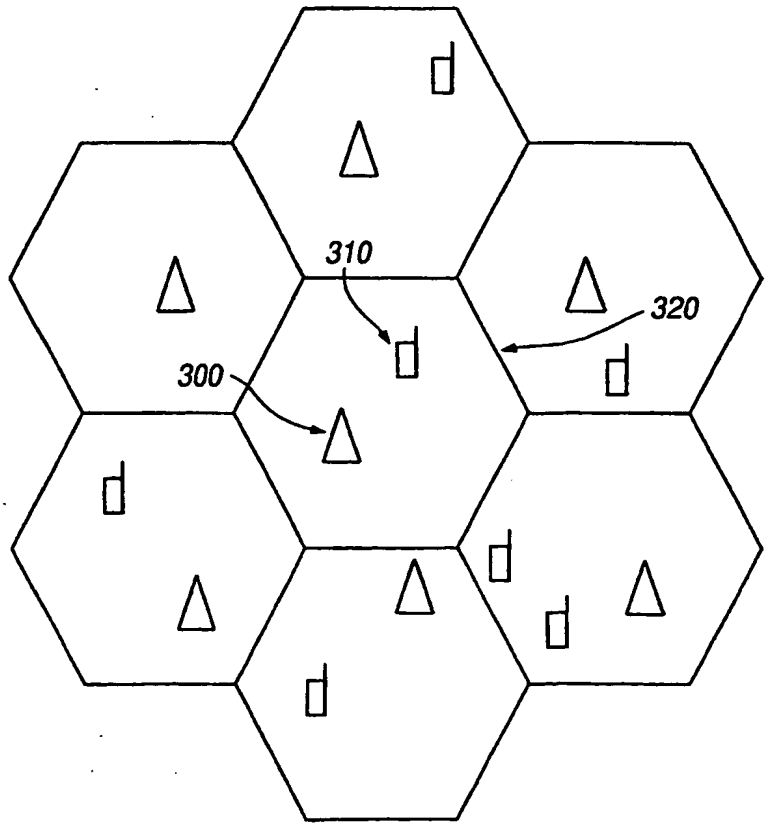
(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **HULBERT, Anthony, Peter** [GB/GB]; 48 Wilton Crescent, Shirley, Southampton, Hampshire SO15 7QH (GB). **WALES, Stephen, William** [GB/GB]; 19 Sovereign Court, 5 Winn Road, Southampton, Hampshire SO17 1EH (GB). **HALLS, Geoffrey, Alan** [GB/GB]; 7 Bramble Drive, Romsey, Hampshire SO51 7RJ (GB). **KOEHN, Reinhard, Walter** [DE/DE]; Homburger Strasse 21, D-14197 Berlin (DE).

(74) Agents: **ALLEN, Derek** et al.; Intellectual Property Department, Siemens Shared Services Limited, Siemens House, Oldbury, Bracknell, Berkshire RG12 8FZ (GB).

[Continued on next page]

(54) Title: METHOD FOR SYNCHRONIZING BASE STATIONS IN A MOBILE COMMUNICATION SYSTEM



(57) Abstract: Described herein is a method of providing synchronisation between a plurality of base stations (300) in a telecommunications system which comprises providing a random access channel in each cell (320). A local base station (300) uses the random access channel in the local cell to transmit a synchronisation signal to neighbouring base stations. For each base station, the time differences between received synchronisation signals from neighbouring base stations and the local synchronisation signal are calculated. Each set of time differences is either used to autonomously synchronise the local base station or is centralised in a radio network controller and a set of corrections distributed from the RNC to the base stations.

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

CORRECTED VERSIONS OF PAMPHLET FRONT PAGES (Continued)

VERSIONS CORRIGÉES DE PAGES DE COUVERTURE DE BROCHURES (Suite)

International Publication Numbers Numéros de publication internationale	International Application Numbers Numéros des demandes internationales	Corrections
WO 00/75045	PCT/RU00/00220	revised abstract received by the International Bureau after completion of the technical preparations for international publication abrégé révisé reçu par le Bureau international après achèvement de la préparation technique en vue de la publication internationale
WO 00/75847	PCT/US00/00271	under (54) published title replaced by correct title sous le numéro (54) le titre publié remplacé par le titre correct
WO 00/76836	PCT/US00/15915	revised abstract received by the International Bureau after completion of the technical preparations for international publication abrégé révisé reçu par le Bureau international après achèvement de la préparation technique en vue de la publication internationale
WO 00/77507	PCT/EP00/05204	published figure cancelled figure publiée supprimée
WO 00/77644	PCT/US00/15713	revised abstract received by the International Bureau after completion of the technical preparations for international publication abrégé révisé reçu par le Bureau international après achèvement de la préparation technique en vue de la publication internationale
WO 00/77805	PCT/US00/14388	revised abstract received by the International Bureau after completion of the technical preparations for international publication abrégé révisé reçu par le Bureau international après achèvement de la préparation technique en vue de la publication internationale
WO 00/78477	PCT/DK00/00326	under (54) published title replaced by correct title sous le numéro (54) le titre publié remplacé par le titre correct
WO 00/79303	PCT/US00/16582	revised abstract received by the International Bureau after completion of the technical preparations for international publication abrégé révisé reçu par le Bureau international après achèvement de la préparation technique en vue de la publication internationale
WO 00/79328	PCT/US00/14712	revised abstract received by the International Bureau after completion of the technical preparations for international publication abrégé révisé reçu par le Bureau international après achèvement de la préparation technique en vue de la publication internationale
WO 01/03859	PCT/SE00/01345	published figure replaced by correct figure figure publiée remplacée par la figure correcte
WO 01/05891	PCT/EP00/05858	revised abstract received by the International Bureau after completion of the technical preparations for international publication abrégé révisé reçu par le Bureau international après achèvement de la préparation technique en vue de la publication internationale
WO 01/06332	PCT/EP00/06216	under (54) published title in German replaced by correct title sous le numéro (54) le titre publié en langue allemande remplacé par le titre correct
WO 01/15340	PCT/GB00/03111	under (54) published title replaced by correct title sous le numéro (54) le titre publié remplacé par le titre correct
WO 01/20171	PCT/US00/25232	under (54) published title replaced by correct title sous le numéro (54) le titre publié remplacé par le titre correct

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(74) Agents: **ALLEN, Derek** et al.; Intellectual Property Department, Siemens Shared Services Limited, Siemens House, Oldbury, Bracknell, Berkshire RG12 8FZ (GB).

(81) Designated States *(national)*: CA, CN, JP, US.

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Published:

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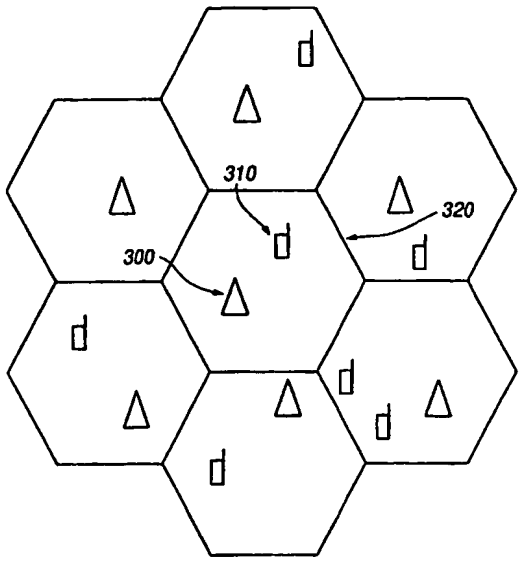
For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: IMPROVEMENTS IN OR RELATING TO MOBILE TELECOMMUNICATIONS SYSTEMS



(57) Abstract: Described herein is a method of providing synchronisation between a plurality of base stations (300) in a telecommunications system which comprises providing a random access channel in each cell (320). A local base station (300) uses the random access channel in the local cell to transmit a synchronisation signal to neighbouring base stations. For each base station, the time differences between received synchronisation signals from neighbouring base stations and the local synchronisation signal are calculated. Each set of time differences is either used to autonomously synchronise the local base station or is centralised in a radio network controller and a set of corrections distributed from the RNC to the base stations.

WO 01/15340 A1

IMPROVEMENTS IN OR RELATING TO MOBILE TELECOMMUNICATIONS SYSTEMS

The present invention relates to improvements in or relating to mobile telecommunications systems and is more particularly concerned with synchronisation of base stations within a telecommunications system.

The UMTS terrestrial radio access time division duplex (UTRA TDD) mode is based on a combination of code division multiple access (CDMA) and hybrid time division multiple access (TDMA). UMTS is an acronym for universal mobile telecommunication system as will be understood by persons skilled in the art.

Reliable operation in the UTRA TDD mode, incorporating the combined TD-CDMA multiple access scheme, requires synchronisation between base stations within a compliant telecommunications system. Moreover the mode also requires the provision of position information for the mobile stations affiliated to each base station. Synchronisation between base stations is also desirable in order to maximise system capacity. To these ends, the synchronisation of base stations must be achieved at the levels of time slots, frames and multi-frames, where a multi-frame is a repeating cycle of a number of frames.

One known mechanism for synchronising the base stations is to equip each base station with a global positioning system (GPS) receiver. However, this is not always appropriate or even possible; for example, an area of deployment may be shadowed from the GPS constellation of satellites by tall buildings. For this and other reasons, alternative mechanisms for synchronising the base stations are required.

In an alternative mechanism, the base stations are synchronised over the backhaul network; the network which enables base stations to switch mobile communications into public telephone networks or the internet. However, if this mechanism is implemented according to a packet protocol (for example, internet protocol (IP) or asynchronous transfer mode (ATM)), then synchronisation will only be possible to a coarse accuracy.

It is therefore an object of the present invention to obviate or at least mitigate the problems of synchronisation of base stations.

In accordance with a first aspect of the present invention, there is provided a method of providing synchronisation between a plurality of base stations in a telecommunications system, for each base station there is a telecommunications cell within which there is at least one mobile station and for each base station the method comprises the steps of: providing at least one channel for usage in the telecommunications cell; a transmission step, wherein said at least one channel is utilised for transmission of a synchronisation signal, the transmission being from a first base station to those remaining base stations within the telecommunications system which are within transmission range; and a first calculation step, in which a time difference between clock pulses from the first base station and clock pulses transmitted by other base stations within transmission range is calculated.

Preferably the method has the further steps: a reporting step, in which each of the plurality of base stations reports the time differences calculated in the time difference calculation step to a radio network controller; a second calculation step, wherein a synchronising adjustment corresponding to each base station is calculated from the reported time differences; and an adjusting step, wherein each base station is individually

sent the corresponding synchronising adjustment and the clock of the base station concerned is adjusted accordingly.

Advantageously, each of the plurality of base stations can act autonomously on the basis of information received from the available remaining base stations to adjust the clock timing of that base station.

The channel utilised for transmission of the synchronisation signal is preferably a random access channel (RACH) which is transmitted at a frequency within a band of frequencies that is provided for communications with mobile stations. The random access channel advantageously comprises a single time slot per TDMA frame. More preferably, the RACH is allocated to transmissions from mobile stations to initiate communications. Preferably, communications are initiated by requesting a resource unit (time slot and CDMA code combination) for uplink usage.

The method preferably further comprises a scheduling step in which the utilisation of each RACH time slot for base station synchronisation is allocated according to a schedule.

More preferably, the method further comprises a silencing step in which a second channel is used by the base station to silence mobile station communications in the RACH time slots to allow the transmission of synchronisation transmissions to other base stations. This second channel is most preferably the broadcast control channel (BCCH).

In accordance with a second aspect of the present invention, there is provided a method of locating a mobile station within a telecommunications cell forming part of a telecommunications system, the telecommunications cell comprising a base station and at least one mobile station, the method comprising the steps of: determining the location of at least three base stations; scheduling synchronisation measurements for

each of the base stations utilising a random access channel; transmitting a signal from the mobile station; receiving the transmitted signal at each of the three base stations; comparing the received signals with timing signals in each of the base stations; and using the comparison at each base station to determine the location of the mobile station.

For a better understanding of the present invention, reference will now be made, by way of example only, to the accompanying drawings in which:-

Figure 1 shows a schematic diagram of the UTRA TDD mode.

Figure 2 shows a schematic diagram of one TDMA frame.

Figure 3 shows a schematic diagram of a network of telecommunication cells.

Figure 4 shows a schematic diagram of the time differences between the signals from base stations.

In Figure 1, the UTRA TDD mode is illustrated. Information is transmitted in bursts at a certain combination of frequency, time (within a frame 102), and coding. Frames 102 are divided into time slots 104 and each time slot is just long enough for a single burst of information. Transmission of information is multiplexed through the use of orthogonal codes (CDMA). The information transmitted within a particular time slot is divided according to these codes: as a result, each burst contains a plurality of independent time slot and code combinations, called resource units 106.

The UTRA TDD mode uses a scheme called Time Division – Code Division Multiple Access (TD-CDMA). This scheme provides for a random access channel (RACH) which is a single time slot 104 per TDMA

frame 102. The RACH is allocated to transmissions from mobile stations to initiate communications, usually by requesting a resource unit 106 for uplink usage. The RACHcan be utilised for both inter base station synchronisation and for mobile station position location.

A TDMA frame is illustrated in Figure 2. As will be apparent, each TDMA frame 200 contains a plurality of time slots 210; fifteen time slots in TDD mode, as shown.

Figure 3 depicts a typical cellular deployment. Each base station 300 has an associated cell 320. The range between neighbouring base stations 300 is roughly double the range from any base station to a mobile station 310 at its cell boundary. In an urban deployment, this typically leads to a path loss which is of the order of 12dB greater to the neighbouring base station 300 than to the cell-edge mobile station 310. On the one hand, the base station 300 would have a height gain advantage over a mobile station 310 at the same location. On the other hand the base station antennas are typically constructed with a 'down tilt' intended to reduce inter cell interference. These opposing effects are of similar magnitude and will tend to cancel, making the 12dB figure a reasonable estimate for the increase in path loss.

Figure 4 shows how the time differences, $d_{i,j}$, between the local base station 'a' and the neighbouring base stations 'b' and 'c' are derived from the synchronisation signals. The shaded time slot represents the RACH which can carry synchronisation signals. The upper boxed area represents the time differences at base 'a': from top to bottom the lines represent: a) the base station's own signal; b) the delayed signal from base station 'b'; and c) the delayed signal from base station 'c'. Similarly the lower boxed area represents the time differences at base 'b'. There is no

line corresponding to base station 'c' – as would be the case when 'c' was out of range of the signal from 'b'.

In the first embodiment of the present invention, there is provided a base station which conforms to the UTRA TDD mode. The base station uses the RACH to synchronise with other base stations which are within transmission range. The base station is arranged to 'steal' the RACH time slot for transmissions to other base stations at suitable times. In this discussion it is assumed that the same time slot will be used for RACH operation in all cells; whilst this assumption is advantageous, it is not essential to the operation of this invention. The times at which a base station should steal a RACH time slot can be determined according to the following criteria:

Firstly, neighbouring base stations must not steal the RACH time slot in the same frame.

Secondly, RACH time slots must be stolen frequently enough to maintain overall base station network synchronisation to the required accuracy.

Lastly, schedules for RACH time slot stealing may be determined either centrally by a radio network controller (RNC) or according to sequence generators resident in the base stations. In the latter case, the sequence generators are arranged in such a way that RACH stealing schedules do not coincide in neighbouring cells. If the RNC is used, it can establish schedules according to this criterion. The schedules may be at regular, pseudo random or constrained random intervals.

When the base station has a schedule assigned for RACH stealing in the near future, at a suitable time it makes a broadcast transmission (preferably on its broadcast control channel, BCCH) to all mobile stations affiliated to the base station, to instruct these mobile stations that the

RACH will be unavailable for mobile station transmissions in the forthcoming scheduled stolen RACH time slot. This will clear the stolen RACH time slot for inter cell synchronisation usage.

Arranging for the stealing base station to silence mobile stations affiliated to the stealing base station when the RACH is stolen, will prevent unnecessary collisions on the RACH channel. However, as described so far, the neighbouring base stations will not silence *their* respective affiliated mobile stations from making RACH transmissions. These RACH transmissions will be power controlled and it should be possible for the neighbouring base stations to receive the transmission from the base station stealing the RACH timeslot and to receive any RACH transmissions from their own affiliated mobile stations. However, in the case where stolen RACH timeslots are scheduled by the RNC, it is optionally possible to arrange for the neighbouring base stations to silence RACH transmissions from their mobile stations using the same procedure as described for the RACH time slot stealing.

In this way the interference to the synchronisation transmission can be substantially removed, except from distant stations. If this option is not employed then interference to the reception of synchronisation transmission in the RACH timeslot may prevent its reception. However, given the statistics of RACH traffic, a high proportion of such measurements should be received.

In the second embodiment of the present invention, an alternative approach to 'stealing' RACH slots for synchronisation is taken. In this approach, RACH slots are arranged throughout the network of base stations to be allocated to synchronisation at regular fixed intervals. During these allocated RACH slots, none of the mobile stations make RACH transmissions, and it is unnecessary to instruct the mobile stations

not to make the RACH transmissions since they are capable of determining such times for themselves. However, the base stations do transmit a simple binary signal periodically to indicate that this mode of operation applies: such a transmission would not be necessary in a network where all base stations had associated GPS receivers. In consequence, during the allocated RACH time slots all base stations are either listening for synchronisation transmissions or making them. The subset of base stations making synchronisation transmissions changes from one selected RACH time slot to the next. It is necessary to ensure that the spread of transmissions is such that only one dominant synchronisation signal is received at any given base station in any given selected RACH time slot. The planning of these subsets can be performed either manually or automatically according to scheme similar to dynamic channel assignment (DCA).

Within UTRA TDD, bursts are transmitted within time slots and each burst is sub-divided into 2560 chips which are zoned into two data fields, one midamble field and a guard period. The midamble field contains training sequences. Because the base stations are static and have accurate frequency references, it is possible to perform correlation across the entire time slot. Correlation makes use of training sequences so the synchronisation burst, with the exception of the guard period, is arranged to have no data fields and effectively becomes all midamble. Whole time slot correlation affords a processing gain of about 34dB. This high processing gain serves to compensate for the increased path loss to the neighbouring cells.

Assuming that every base station sends and receives synchronisation bursts to and from its neighbouring base stations, all of the information necessary for the network wide synchronisation can be

aggregated. This can be used in one of two distinct ways, either distributed or centralised.

The first and second embodiments of the invention detail methods of gaining access to RACH timeslots. Either embodiment can be implemented according to the distributed or centralised approaches.

In the distributed approach, every base station acts autonomously on the basis of the information it has received to adjust its clock timing in such a way that, given that all other base stations operate similarly, they will come into synchronisation.

In the centralised approach, all base stations report their results to the RNC which then computes a set of adjustments and signals these adjustments individually to the relevant base stations. Essentially, each base station measures the timing of each received synchronisation burst relative to its own timing. This can be viewed as the timing of the received burst relative to the time at which it would make its transmission. Each base station is provided with a matched filter, matched to the synchronisation code. When a burst is received, there will usually be several discrete paths. The earliest significant path will be taken to provide the timing since this is most likely to correspond to the line of sight path if there is one. The following discussion relates to the centralised synchronisation procedure, following coarse level synchronisation.

Suppose we have a deployment of N base stations. Let the variable $L(i,j) = L(j,i)$ indicate those base stations which are able to hear each other's synchronisation transmissions. If base station i can hear base station j's transmission and base station j can hear base station i's transmission then $L(i,j) = L(j,i) = 1$. Otherwise $L(i,j) = L(j,i) = 0$. Note that $L(i,i) = 0$ for all i. All relative timings are aggregated at the RNC. If

base station i hears base station j's transmission with delay $d_{i,j}$ and base station j hears base station i's transmission with delay $d_{j,i}$, then the RNC computes the time differences as

$$\delta_{i,j} = \frac{d_{i,j} - d_{j,i}}{2}$$

and

$$\delta_{j,i} = \frac{d_{j,i} - d_{i,j}}{2} = -\delta_{i,j}$$

Referring once more to Figure 4, it is plain that $L(a,b) = L(b,a) = 1$ and $L(a,c) = L(c,a) = 1$ but $L(b,c) = L(c,b) = 0$. Figure 4 also illustrates how the time differences, $d_{i,j}$, are derived. Thus $\delta_{i,j}$ is the time by which base station i's time is advanced with respect to the time of base station j and excludes any time delay due to intervening distance.

Suppose base station i will be retarded by a compensation amount C_i which is to be computed. Following such compensation, the new timing error between base stations i and j will be given by

$$\delta'_{i,j} = \delta_{i,j} - C_i + C_j$$

If all measurements were completely accurate and consistent, we could simply solve the equations to make $\delta'_{i,j} \equiv 0$ for all i and all j.

However, given measurement errors it is better to solve for a minimum sum square error, that is,

$$\sum_{i=1}^{N}\sum_{j=1}^{N} L(i,j)\,\delta'^{2}_{i,j}$$

should be minimised. Expanding this gives:-

$$\sum_{i=1}^{N}\sum_{j=1}^{N} L(i,j)\left\{\delta^2_{i,j} + C_i^2 + C_j^2 + 2\left(\delta_{i,j}.C_j - \delta_{i,j}.C_i - C_i.C_j\right)\right\}$$

Let $M(i) = \sum_{j=1}^{N} L(i,j)$ be the number of base stations whose synchronisation transmissions base station i can hear and who can also

hear base station i's synchronisation transmission. We can then express the sum square error as

$$2\sum_{i=1}^{N} M(i)C_i^2 + \sum_{i=1}^{N}\sum_{j=1}^{N} L(i,j)\delta_{i,j}^2 - 4\sum_{i=1}^{N} C_i \sum_{j=1}^{N} L(i,j)\delta_{i,j} - 2\sum_{i=1}^{2}\sum_{j=1}^{N} L(i,j)C_j$$

Now differentiate with respect to C_i and equate to zero. We obtain

$$4M(i)C_i - 4\sum_{j=1}^{N} L(i,j)\delta_{i,j} - 4\sum_{j=1}^{N} L(i,j)C_j = 0$$

Thus

$$M(i)C_i - \sum_{j=1}^{N} L(i,j)C_j = \sum_{j=1}^{N} L(i,j)\delta_{i,j}$$

We can express this in matrix notation as

$$(\mathrm{diag}(\mathbf{M}) - \mathbf{L})\mathbf{C} = \mathbf{D}$$

where $\mathrm{diag}(\mathbf{M})$ is the diagonal matrix with elements $M(i)$, $i \in \{1...N\}$ along the diagonal,

L is the matrix with elements $L(i,j)$,

C is the vector with elements C_i, and

D is a vector with elements

$$D_i = \sum_{j=1}^{N} L(i,j)\delta_{i,j} = \sum_{j=1}^{M(i)} \delta_{i,S_j(i)}$$

where $S_j(i)$, $j \in \{1...M(i)\}$ is the set of indices of base stations to and from which base station i can send and receive synchronisation transmissions respectively.

Let $\mathbf{A} = (\mathrm{diag}(\mathbf{M}) - \mathbf{L})$

This matrix is singular, i.e. has no inverse. This reflects the fact that any common value can be added to all compensation values, C_i, without affecting the sum square error. A reasonable constraint to apply to the compensation values is that their sum should be zero so as to minimise the overall drift. Thus, we have an additional equation:-

$$\sum_{i=1}^{N} C_i = 0$$

This can be reflected in the matrix equation by adding a row of ones to any of the rows in A to form A'.

We can now solve the equation to obtain the compensation values. However, we can note that A (and therefore A') does not change very rapidly, if at all, since it is a function only of the base station connectivity. Thus, it may be more efficient to compute the inverse of A' which need only be updated infrequently. We thus obtain:-

$$\mathbf{C} = (\mathbf{A'})^{-1} \cdot \mathbf{D}$$

Having these compensation values, C_i, each base station in the telecommunications system can be synchronised with every other base station. In addition to fulfilling the requirements of UTRA TDD mode, synchronisation is important in locating mobile stations.

A mobile station may need to be located within its cell, notably when the user makes an emergency call or simply in order to ensure a clean hand-over as the mobile station crosses into a neighbouring cell. Position measurements can be performed on the basis of delay measurements. A minimum of three base stations must be involved in the measurements in order to obtain an unambiguous location. This is because two dimensions of space plus time must be determined. In order for such positioning to be performed the base stations involved must either be synchronised or at least know their mutual time difference to a high accuracy. The periodic updating described earlier may not provide accurate enough synchronisation for position location.

According to the third embodiment of the present invention, requesting the location of a mobile station initiates a set of synchronisation

measurements between the base stations involved. Before this can be done, it must be determined which base stations are involved. The simplest, although least efficient, approach to determining this set of measurements is to assume that the base station to which the mobile station is affiliated and the list of base stations neighbouring that base station are all involved.

A more efficient approach would be to arrange for the mobile station to monitor the signal strength of the BCCH channels of the neighbouring base stations and report the addresses of the two (or more) base stations providing the strongest signals. Alternatively, the mobile stations can simply report the actual BCCH signal strength and the receiving base station or the RNC can determine the base stations to be involved. The BCCH signal strength can be measured by correlating against the appropriate training sequences. It will be understood that these measurements will be performed anyway to support the hand-over decision process.

Once the set of base stations involved has been determined, the schedules for synchronisation measurements can be established for each base station. The procedure is then identical to that described previously for normal synchronisation. The mobile station is also instructed to make, at a suitable time, a transmission at full power on the RACH using, preferably, the same burst structure as defined earlier for inter base station transmissions. The time for this transmission should be close to the transmission times for the inter base station synchronisation transmission in order to minimise the effect of clock drift. However, the mobile station transmission may be before, interspersed with or after the inter base station synchronisation transmissions. In a preferred implementation, the RNC will select the schedule for the mobile station to make its transmission.

This will be signalled to the mobile station on a suitable signalling channel by the base station to which it is affiliated. Other means of scheduling are not precluded. The RNC will also instruct the base stations involved to signal, preferably in their BCCH channel, to their affiliated mobile stations that random access transmission is unavailable in that particular RACH time slot.

Alternatively, this RNC instruction may be restricted to just the base station to which the mobile station is affiliated. The rationale for this restriction is that the mobile station is transmitting at full power and so can easily reach the base station at the centre of its own cell with enough power to make RACH reception possible. However, the range to the other base stations will typically be greater than the range from any mobile station attempting to transmit in a RACH within the cells of those other base stations. Since these cells will use power control, it is possible for the processing gain between the various training sequences to facilitate simultaneous reception.

The three (or more) base stations will each receive the signal from the mobile station and compare the reception time with their own timing. Given that the positions of the base stations will be known, this will provide all of the information needed to locate the mobile station.

Following any of the various transmissions required to support positioning, it may be discovered that either inter base station synchronisation transmissions or the transmission from the mobile station have not been received adequately. The RNC can schedule repeat transmissions as necessary, either to facilitate computation of the position or to improve its accuracy.

So far the discussion of synchronisation has covered only fine synchronisation after coarse synchronisation has already been achieved.

With an RNC in control, initial coarse synchronisation can be achieved in a straightforward manner. When a network is commissioned the base stations may be activated in sequence either by manual intervention or under control of the RNC. The first base station to be activated becomes the temporary timing master and makes periodic synchronisation burst transmissions in its RACH channel. Other base stations, activated later are only allowed to transmit after they have received a synchronisation burst. In this way the network will become synchronised globally. If an individual base station requires re-synchronisation, following a failure and repair, for example, again that base station is not allowed to transmit until it has received a RACH synchronisation burst from at least one other base station. It may then make its own RACH burst transmission, after making a coarse update to its timing from the initial burst.

The above achieves slot and frame synchronisation since the RACH slot is in a fixed position within the frame. Multi-frame synchronisation can be achieved by a number of means. The simplest and preferred method is to make the RACH slot which is 'stolen' for synchronisation always be contained in the first frame or any fixed arbitrary numbered frame within a multi-frame.

None of the above description precludes the incorporation of base stations equipped with a GPS receiver. In this case, the compensation values, C_i, for those base stations are set equal to zero and the constraint that the sum of compensation values equals zero is removed. In this way, the synchronisation scheme will cause all of the base stations involved to become synchronised either directly or indirectly to GPS.

CLAIMS:

1. A method of providing synchronisation between a plurality of base stations in a telecommunications system, the telecommunications system comprising a plurality of cells, each of the plurality of cells having one of the plurality of base stations and at least one mobile station, the method comprises the steps of:

a) providing at least one channel for usage in the plurality of cells;

b) transmitting a synchronisation signal in a given one of the at least one channel, the transmission being from a first base station to those remaining base stations within the telecommunications system which are within transmission range; and

c) calculating a time difference between clock pulses from the first base station and clock pulses transmitted by other base stations within transmission range.

2. A method according to Claim 1, having the further steps of:

d) for each of the plurality of base stations, reporting the time differences calculated in step c) to a radio network controller;

e) calculating a synchronising adjustment corresponding to each base station is calculated from the reported time differences;

f) informing each base station individually of the corresponding synchronising adjustment calculated in step e); and

g) adjusting the clock pulses of each base station according to the corresponding synchronising adjustment.

3. A method according to Claim 1, having the further step of:

h) the first base station acting autonomously on the time differences calculated in step c) by adjusting the clock pulses of the first base station to minimise the time differences.

4. A method according to Claims 1, 2 or 3, wherein the given channel is a random access channel transmitted at a frequency within a band of frequencies that is provided for communications with mobile stations.

5. A method according to Claim 4, wherein the random access channel comprises a time slot per TDMA frame.

6. A method according to Claim 5, wherein the random access channel is allocated to uplink transmissions in order to initiate communications.

7. A method according to Claim 6, wherein communications are initiated by requesting a resource unit for uplink usage.

8. A method according to Claims 5, 6 or 7, having the further step of:

i) allocating the utilisation of each random access channel time slot for base station synchronisation according to a schedule.

9. A method according to any one of Claims 5,6 or 7, having the further step of:

j) using a second one of said at least one channels to silence uplink communications in the random access channel time slots to allow the transmission of synchronisation transmissions from the first base station to other base stations.

10. A method according to Claim 9, wherein the second channel is the broadcast control channel.

11. A method according to any one Claims 4 to 10, wherein the random access channel time slot used is always contained in a fixed numbered frame within a plurality of multi-frames in order to synchronise the plurality of base stations over multi-frames.

12. A method of locating a mobile station within a telecommunications cell forming part of a telecommunications system, the telecommunications cell comprising a base station and at least one mobile station, the method comprising the steps of:

determining the location of at least three base stations;

scheduling synchronisation measurements for each of the base stations utilising a random access channel;

transmitting a signal from the mobile station;

receiving the transmitted signal at each of the three base stations;

comparing the received signals with timing signals in each of the base stations; and

using the comparison at each base station to determine the location of the mobile station.

13. A method of providing synchronisation between a plurality of base stations in a telecommunications system, the method substantially as hereinbefore described with reference to the accompanying drawings.

14. A method of locating a mobile station within a telecommunications cell forming part of a telecommunications system, substantially as hereinbefore described with reference to the accompanying drawings.

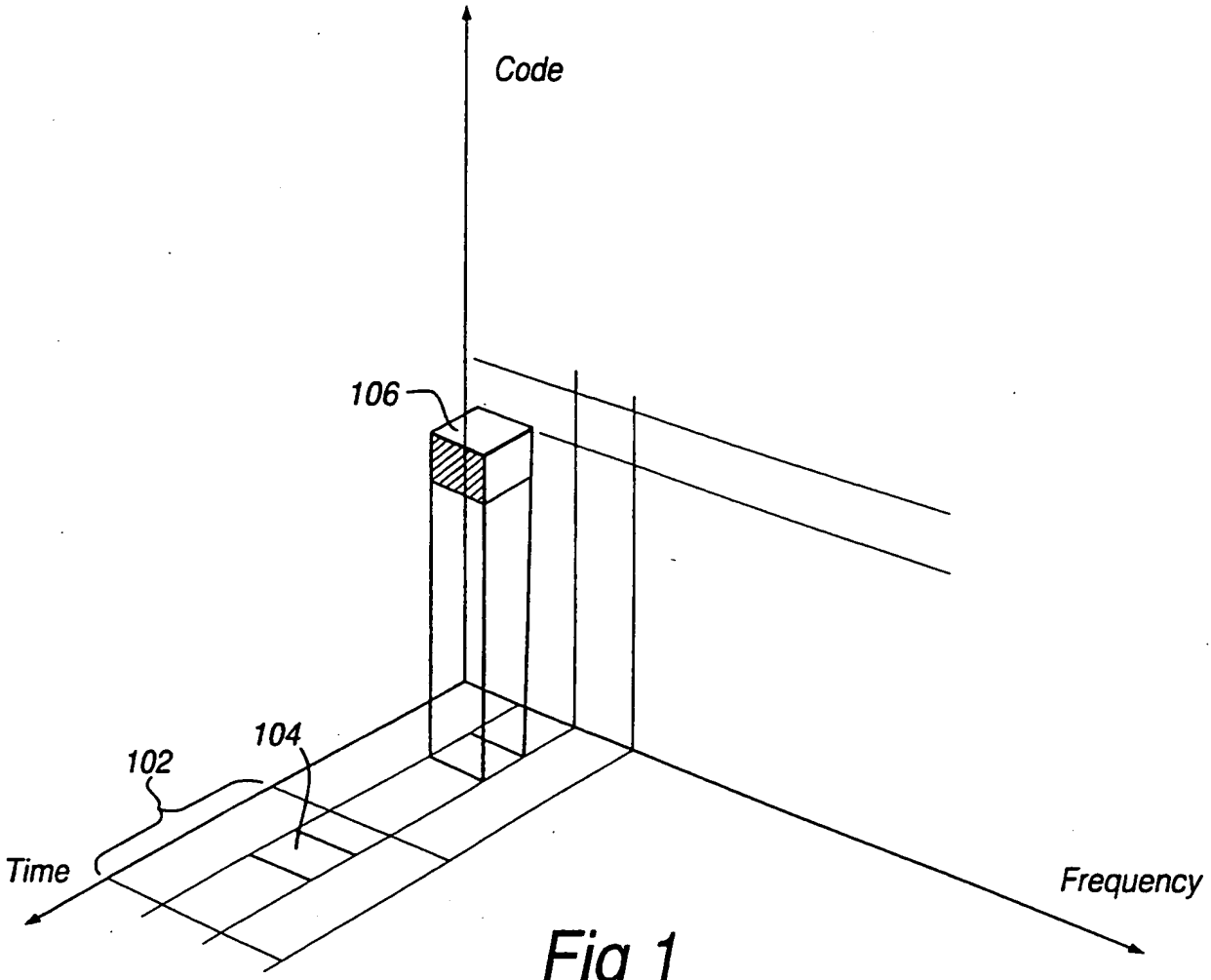


Fig 1

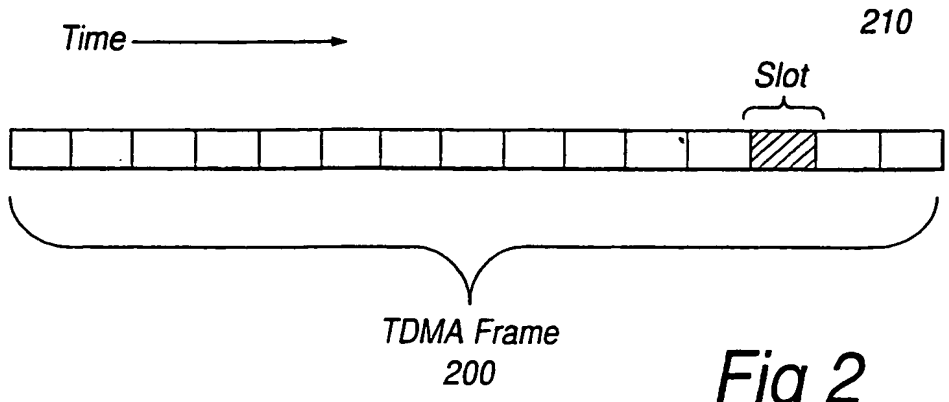


Fig 2

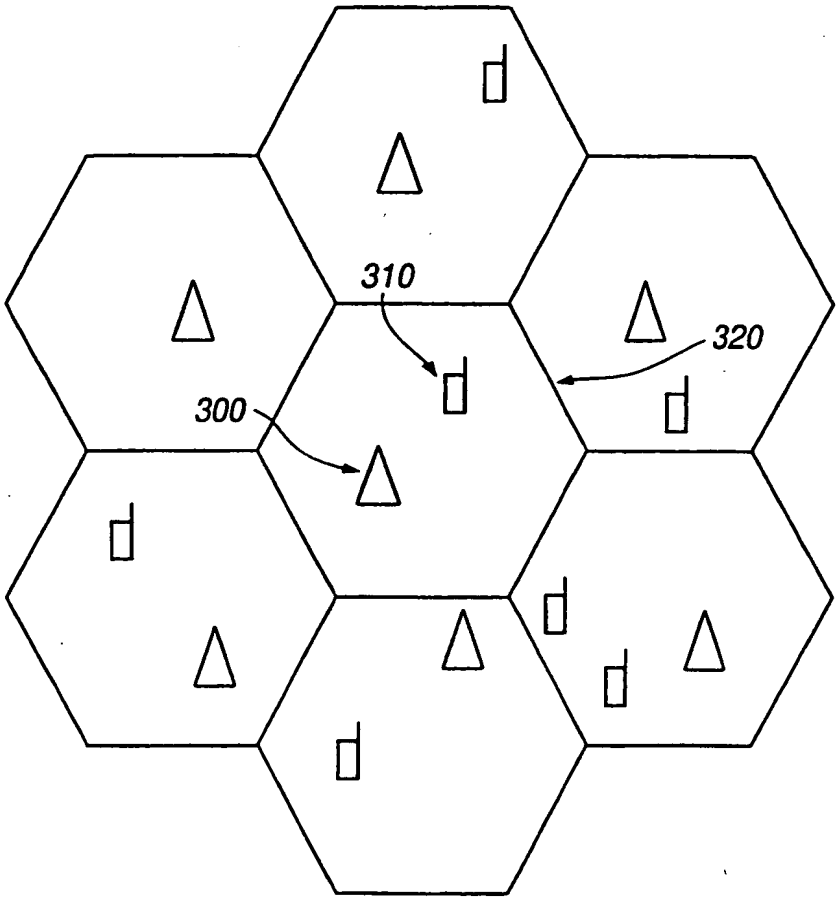


Fig 3

3/3

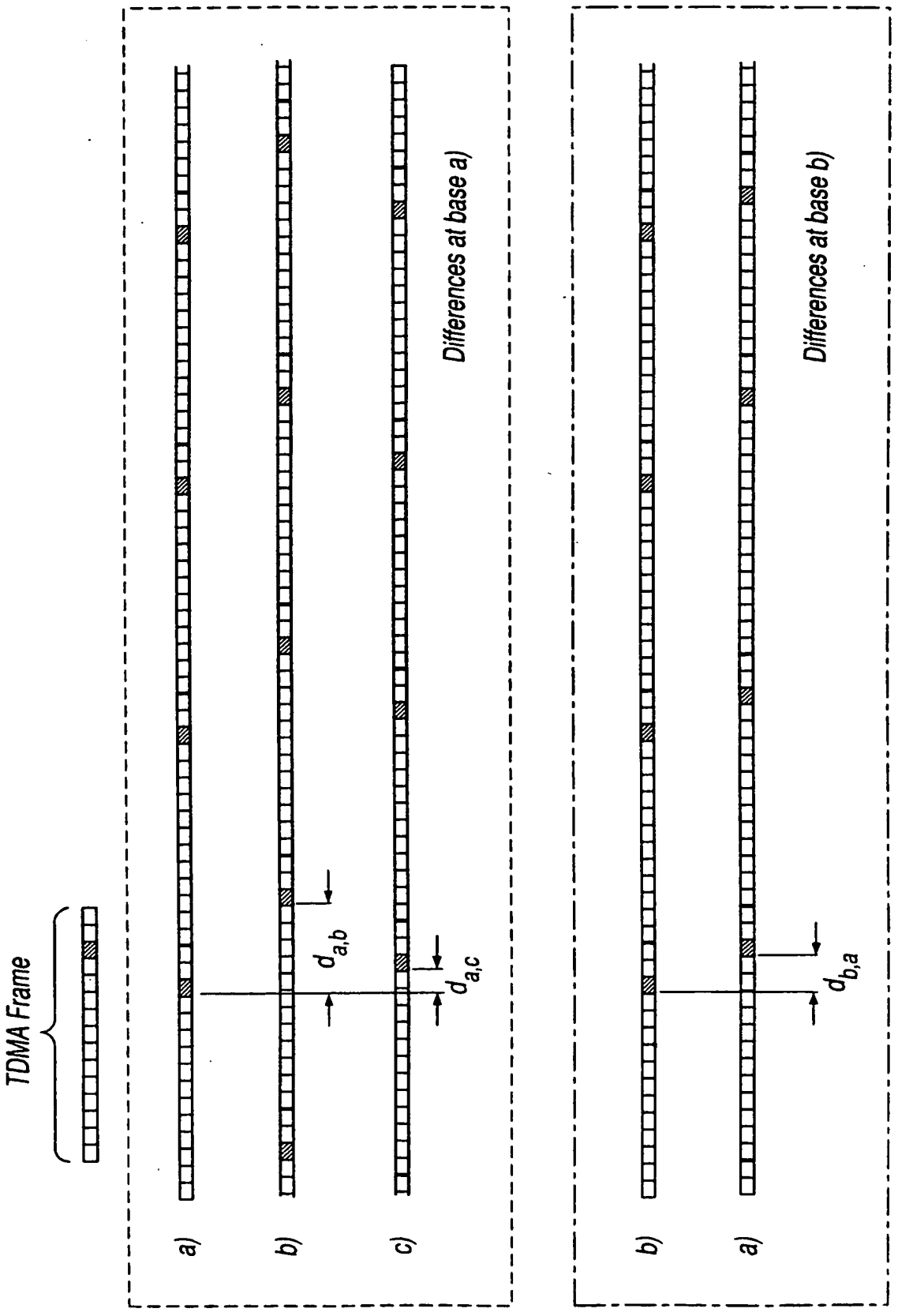

TDMA Frame
a)
b)
c)
$d_{a,b}$
$d_{a,c}$
Differences at base a)
b)
a)
$d_{b,a}$
Differences at base b)

Fig 4

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 00/03111

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04B7/26 H04Q7/38

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04B H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, INSPEC, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	LAGRANGE X ET AL: "AUTONOMOUS INTER BASE STATION SYNCHRONISATION VIA A COMMON BROADCAST CONTROL CHANNEL" PROCEEDINGS OF THE VEHICULAR TECHNOLOGY CONFERENCE,US,NEW YORK, IEEE, vol. CONF. 44, 8 June 1994 (1994-06-08), pages 1050-1054, XP000496838 ISBN: 0-7803-1928-1 page 1050, left-hand column, line 1 -page 1052, right-hand column, line 10 ---	1,3,13, 14
X	EP 0 817 405 A (NIPPON ELECTRIC CO) 7 January 1998 (1998-01-07) column 1, line 1 -column 4, line 22 ---	1,3,13, 14
	-/--	

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 January 2001	12 02 2001

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Larcinese, A

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 00/03111

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
P,X	WO 99 57826 A (NOKIA TELECOMMUNICATIONS OY ;ESSER ALEX (FI); WESBY PHILIP (FI)) 11 November 1999 (1999-11-11) page 7, line 25 -page 16, line 34 figure 7	1-4
X	WO 92 05672 A (TELEVERKET) 2 April 1992 (1992-04-02) page 3, line 27 -page 5, line 23	12
X	EP 0 800 319 A (HEWLETT PACKARD CO) 8 October 1997 (1997-10-08) column 6, line 13 - line 39 column 7, line 15 -column 8, line 18 figure 3	12

Form PCT/ISA/210 (continuation of second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/GB 00/03111

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☒ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☒ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. Claims: 1-11,13,14

2. Claim : 12

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/GB 00/03111

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0817405 A	07-01-1998	JP 10094044 A	10-04-1998
		US 5936947 A	10-08-1999
WO 9957826 A	11-11-1999	AU 3826499 A	23-11-1999
WO 9205672 A	02-04-1992	SE 466376 B	03-02-1992
		DE 69119085 D	30-05-1996
		DE 69119085 T	22-08-1996
		EP 0551310 A	21-07-1993
		JP 6500902 T	27-01-1994
		SE 9002920 A	03-02-1992
EP 0800319 A	08-10-1997	US 6061565 A	09-05-2000

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
1999P04839 WO		
International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/GB00/03111	11/08/2000	24/08/1999
International Patent Classification (IPC) or national classification and IPC H04B7/26		
Applicant ROKE MANOR RESEARCH LIMITED et al.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 8 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 3 sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the report
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☒ Lack of unity of invention
   - V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   - VI ☒ Certain documents cited
   - VII ☒ Certain defects in the international application
   - VIII ☒ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
22/03/2001	07.12.2001
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Staeger, R Telephone No. +49 89 2399 8124

Form PCT/IPEA/409 (cover sheet) (January 1994)

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/GB00/03111

I. Basis of the report

1. With regard to the **elements** of the international application *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17))*:
Description, pages:

1-15	as originally filed				
Claims, No.:					
13,14	as originally filed				
1-12	as received on	19/11/2001	with letter of	19/11/2001	
Drawings, sheets:					
1/3-3/3	as originally filed				

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

   These elements were available or furnished to this Authority in the following language: , which is:

   - ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
   - ☐ the language of publication of the international application (under Rule 48.3(b)).
   - ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

   - ☐ contained in the international application in written form.
   - ☐ filed together with the international application in computer readable form.
   - ☐ furnished subsequently to this Authority in written form.
   - ☐ furnished subsequently to this Authority in computer readable form.
   - ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
   - ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

- ☐ the description, pages:
- ☒ the claims, Nos.: 13-14
- ☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

   (Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

IV. Lack of unity of invention

1. In response to the invitation to restrict or pay additional fees the applicant has:

   ☐ restricted the claims.

   ☐ paid additional fees.

   ☐ paid additional fees under protest.

   ☒ neither restricted nor paid additional fees.

2. ☐ This Authority found that the requirement of unity of invention is not complied and chose, according to Rule 68.1, not to invite the applicant to restrict or pay additional fees.

3. This Authority considers that the requirement of unity of invention in accordance with Rules 13.1, 13.2 and 13.3 is

   ☐ complied with.

   ☐ not complied with for the following reasons:

4. Consequently, the following parts of the international application were the subject of international preliminary examination in establishing this report:

   ☐ all parts.

   ☒ the parts relating to claims Nos. 1-11.

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims 2,4-11
	No:	Claims 1,3

Inventive step (IS)	Yes:	Claims	
	No:	Claims	2,4-11
Industrial applicability (IA)	Yes:	Claims	1-11
	No:	Claims	

2. Citations and explanations
see separate sheet

VI. Certain documents cited

1. Certain published documents (Rule 70.10)

and / or

2. Non-written disclosures (Rule 70.9)

see separate sheet

VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:
see separate sheet

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:
see separate sheet

IV. Lack of Unity

In response to the invitation to restrict or pay additional fees, the applicant neither restricted nor paid additional fees. Consequently, a report will be indicated merely with regard to claim 1-11 and not for claim 12.

V. Reasoned statement with regard to novelty and inventive step:

1) Reference is made to the following documents:

D1: LAGRANGE X ET AL: 'AUTONOMOUS INTER BASE STATION SYNCHRONISATION VIA A COMMON BROADCAST CONTROL CHANNEL' PROCEEDINGS OF THE VEHICULAR TECHNOLOGY CONFERENCE,US,NEW YORK, IEEE, vol. CONF. 44, 8 June 1994, pages 1050-1054, XP000496838 ISBN: 0-7803-1928-1

D2: EP-A-0 817 405 (NIPPON ELECTRIC CO) 7 January 1998

D3: WO 99 57826 A (NOKIA TELECOMMUNICATIONS OY ;ESSER ALEX (FI); WESBY PHILIP (FI)) 11 November 1999

2a) Although claim 1 is related to "a method of **providing synchronization** between a plurality of base stations", said claim merely contains features c) where therein are calculated for a base station the time differences between corresponding time slots transmitted by the base station and corresponding time slots received from other base stations within the transmission range of said base station. Thereby, **merely several time difference values have been calculated and provided.** Claim 1 does neither contain any clear feature that these values are used for adjusting (providing) synchronization nor does the claim disclose features how these values are used to provide synchronization between the base stations. This leads to an unclear scope of the claim (see also section VIII). Moreover, with regard to novelty and inventive step merely those features occurring in the claim are taken into account for the following opinion.

b) Claim 1 is formulated in such a general manner that the features of said claim can be read from D1. In the following references to D1 will be indicated in brackets. Document D1, in particular abstract, section synchronization algorithm and conclusion, discloses as in claim 1:

A method of providing synchronisation between a plurality of base stations in a telecommunications system (abstract, l. 1-2) , the telecommunications system comprising a plurality of cells, each of the plurality of cells having one of the plurality of base stations and at least one mobile station, the method comprises the steps of:
a) providing at least one channel comprising time slots (TDMA) for usage in the plurality of cells;
b) transmitting a synchronisation signal in a given time slot (TDMA time slots) of the at least one channel, the transmission being from each of the plurality of base stations to those remaining base stations within the telecommunications system which are within transmission range of each respective base station (implied in D1, that only stations being within transmission range can be received); and
c) for each respective base station, calculating respective time differences between corresponding time slots transmitted by the respective base station and received from respective other base stations within the transmission range of the respective base station (abstract, l. 11-13 and section III, synchronization algorithm).

Hence, claim 1 of the present application does not satisfy the criterion set forth in Article 33(2) PCT, because the subject-matter of claim 1 is not new compared to D1.

Claim 1 merely seems to differ from D1 in that claim 1 is omitting the weighting averaging of D1 and claim 1 is not using the averaged time difference for the synchronization of the base station, which has calculated the averaged time difference. Apart from the obviously simpler design of the method, the only result such an omission is that the effects related to these features are also no longer present. Furthermore it could also be argued that when having the problem to simplify a method the skilled person would take into a account to avoid as much calculations as possible.
Thus, even if the claim would be new based on minor differences it would appear that omitted features compared to D1 could not provide an inventive contribution to claim 1.

For the objections above has been taken into account that according to D1,

section "synchronization algorithm" **and the cited prior art documents [9] and [10] of D1**, a base station autonomously adjusts its synchronisation based on the time differences between its time and the time related to received signals of the neighbouring base stations. These time differences were weighted and averaged and then autonomously the base station uses this averaged value to adjust its own timing. Each base station performs such a process and appears that there is no transmitting of these average values between the base stations.

c) D2 does not clearly indicate a method for synchronising base stations. However, D2, in particular figures 1, 2 and 5 and col. 1, l. 3 to col. 4, l. 21; discloses a method for a base station to detect TDMA transmissions made by adjacent base stations and uses the detected transmission timings of the adjacent base stations to determine the transmit time intervals of the detecting base station in such a manner that there is no conflict with the control channel signals of the adjacent base station. Such a controlled determining and adjusting of a transmit time slot is considered to fall under the term "synchronisation".
Thus, it appears that most of the **features contained in claim 1** can be found, also in D2. The minor difference do not appear to contribute inventive subject-matter.

3a) Prima facie dependent claim 3 does not contain any features which, in combination with the features of any claim to which it refers, meet the requirements of the PCT in respect of novelty, because the feature of claim 3 seems to shown in D1 and D2 as cited above.

b) Prima facie the features of dependent claims 2,4-11 appear to be routine design options for the skilled person and thereby do not contribute subject-matter which could provide an inventive step.

VI Certain documents

Since the priority of the application is considered as valid, the document D3 does not belong to prior art in the PCT phase, but has to be to be taken into account in a possible European phase.

VII Certain defects in the international application:

1.) To meet the requirements of Rule 5.1(a)(ii) PCT, documents D1- D2 should have been identified in the description and the relevant background art disclosed therein should be briefly discussed.

2.) If necessary, the description should have been adapted to correctly reflect any changes in the scope of the claimed invention.

VIII Certain observations:

1) As mentioned already in section 2a.) above claim 1, although related to "a method of **providing synchronization** between a plurality of base stations", said claim merely contains a feature c) where therein are calculated for a base station the time differences between corresponding time slots transmitted by the base station and corresponding time slots received from other base stations within the transmission range of said base station. Thereby, **merely several time difference values have been calculated and no features are indicated that and how these values are used for synchronizing.**
There should have been at least a feature like: "using for each respective base station the calculated respective time differences for adjusting the synchronisation between the plurality of base stations".

2) In order to avoid unclear antecedents of **respective** base station and **respective** other base stations, it seemed to be clearer if in claim 1, l. 16 there would have been deleted the word "respective" in front of "other base stations".

Demand on int 24/5/01
Not Reg Phase
24/12/02

WO 01/15340
PCT/GB00/03111

cc RMRL

ENT COOPERATION TREA

From the INTERNATIONAL BUREAU

PCT

NOTICE INFORMING THE APPLICANT OF THE COMMUNICATION OF THE INTERNATIONAL APPLICATION TO THE DESIGNATED OFFICES

(PCT Rule 47.1(c), first sentence)

To:
ALLEN, Derek
Intellectual Property Department
Siemens Shared Services Limited
Siemens House, Oldbury
Bracknell, Berkshire RG12 8FZ
ROYAUME-UNI

CF.

Date of mailing (day/month/year) 01 March 2001 (01.03.01)	
Applicant's or agent's file reference 1999P04839	**IMPORTANT NOTICE**
International application No. PCT/GB00/03111	**International filing date** (day/month/year) 11 August 2000 (11.08.00)
Priority date (day/month/year) 24 August 1999 (24.08.99)	
Applicant ROKE MANOR RESEARCH LIMITED et al	

1. Notice is hereby given that the International Bureau has communicated, as provided in Article 20, the international application to the following designated Offices on the date indicated above as the date of mailing of this Notice:
   US

   In accordance with Rule 47.1(c), third sentence, those Offices will accept the present Notice as conclusive evidence that the communication of the international application has duly taken place on the date of mailing indicated above and no copy of the international application is required to be furnished by the applicant to the designated Office(s).

2. The following designated Offices have waived the requirement for such a communication at this time:
   CA,CN,EP,JP

   The communication will be made to those Offices only upon their request. Furthermore, those Offices do not require the applicant to furnish a copy of the international application (Rule 49.1(a-bis)).

3. Enclosed with this Notice is a copy of the international application as published by the International Bureau on
   01 March 2001 (01.03.01) under No. WO 01/15340

REMINDER REGARDING CHAPTER II (Article 31(2)(a) and Rule 54.2)

If the applicant wishes to postpone entry into the national phase until 30 months (or later in some Offices) from the priority date, a **demand for international preliminary examination** must be filed with the competent International Preliminary Examining Authority before the expiration of 19 months from the priority date.

It is the applicant's sole responsibility to monitor the 19-month time limit.

Note that only an applicant who is a national or resident of a PCT Contracting State which is bound by Chapter II has the right to file a demand for international preliminary examination.

REMINDER REGARDING ENTRY INTO THE NATIONAL PHASE (Article 22 or 39(1))

If the applicant wishes to proceed with the international application in the **national phase**, he must, within 20 months or 30 months, or later in some Offices, perform the acts referred to therein before each designated or elected Office.

For further important information on the time limits and acts to be performed for entering the national phase, see the Annex to Form PCT/IB/301 (Notification of Receipt of Record Copy) and Volume II of the PCT Applicant's Guide.

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland**	Authorized officer J. Zahra
Facsimile No. (41-22) 740.14.35	Telephone No. (41-22) 338.83.38

Form PCT/IB/308 (July 1996)

3855566

Continuation of Form PCT/IB/308

NOTICE INFORMING THE APPLICANT OF THE COMMUNICATION OF THE INTERNATIONAL APPLICATION TO THE DESIGNATED OFFICES

Date of mailing (day/month/year)	IMPORTANT NOTICE
01 March 2001 (01.03.01)	
Applicant's or agent's file reference	**International application No.**
1999P04839	PCT/GB00/03111

The applicant is hereby notified that, at the time of establishment of this Notice, the time limit under Rule 46.1 for making amendments under Article 19 has not yet expired and the International Bureau had received neither such amendments nor a declaration that the applicant does not wish to make amendments.

IDS

The Patent Office

INVESTOR IN PEOPLE

Roke Manor Research Limited
% Siemens Group Services Limited
Siemens House
Oldbury
BRACKNELL
RG12 8FZ

The Patent Office
Concept House
Cardiff Road
Newport
South Wales
NP10 8QQ

Examiner: 01633 814380
†**E-mail:** Anita.Keogh@patent.gov.uk
Switchboard: 01633 814000
Fax: 01633 814444

Your Reference: 1999P04839/GB/R76/MM/cs
Application No: GB 0007143.1 – 2nd priority date

26 September 2000

Dear Sirs

Patents Act 1977: Search Report under Section 17(5)

I enclose two copies of my search report and two copies of the citations.

Plurality of invention

I consider that your application relates to more than one invention as follows:

a) the invention of claims 1-11 & 13 defining a method to provide synchronisation between a plurality of base stations
b) the invention of claims 12 & 14 defining a method of locating a mobile station using synchronised base stations

My search report relates to the first invention only. If you want the other invention searched, you should file a further Patents Form 9/77.

Publication

I estimate that, provided you have met all formal requirements, preparations for publication of your application will be completed soon after **16 January 2001**. You will then receive a letter informing you of completion and telling you the publication number and date of publication.

Amendment/withdrawal

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†**Use of E-mail:** Please note that e-mail should be used for correspondence only.

If you wish to file amended claims for inclusion with the published application, or to withdraw the application to prevent publication, you must do so before the preparations for publication are completed. **No reminder will be issued.** If you write to the Office less than 3 weeks before the above completion date, please mark your letter prominently: "URGENT - PUBLICATION IMMINENT".

Yours faithfully

Anita Keogh
Examiner

The Patent Office

INVESTOR IN PEOPLE

Application No: GB 0007143.1
Claims searched: 1-11

Examiner: Anita Keogh
Date of search: 25 September 2000

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.R): H4L (LDLTA, LDLTX, LDLW, LECY)

Int Cl (Ed.7): H04B (7/204, 7/212, 7/26), H04J (3/06), H04Q (7/30)

Other: Online: WPI, EPODOC, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X, P	EP 0954122 A	(SIEMENS) see abstract	1 at least
A	EP 0903873 A1	(TOSHIBA) see columns 1-7	
X	EP 0560079 A1	(TECNOMEN) see abstract and particularly page 3 lines 23-39, page 4 line 32 to page 5 line 25	1, 2
A	EP 0286614 A1	(ERICSSON) see abstract and particularly column 8 line 47 to column 9 line 33	
X, P	WO 99/57826 A1	(NOKIA) see abstract and particularly page 13 line 27 to page 16 line 34	1, 2
X	WO 94/28643 A1	(NOKIA) see abstract and particularly page 2 line 14 to page 3 line 30, page 8 line 30 to page 9 line 32	1, 3, 4
X	US 5448570	(TODA et al.) see column 1 lines 35-61 column 2 lines 31-53	1, 3
A	US 5363376	(CHUANG et al.) see abstract and column 10 lines 12-38	

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Roke Manor Research Limited
% Siemens Shared Services Limited
Siemens House
Oldbury
Bracknell
RG12 8FZ

CF

The Patent Office
Patents Directorate

Concept House
Cardiff Road, Newport
South Wales NP10 8QQ

Examiner: 01633 813660
†**E-mail:** david.mcwhirter@patent.gov.uk
Switchboard: 01633 814000
Fax: 01633 814444
Minicom: 08459 222250
DX 722540/41 Cleppa Park 3
http://www.patent.gov.uk

Your Reference: 1999P04839/GB/R76/MM/cs
Application No: GB 0007143.1

4 June 2003

Dear Sirs

Patents Act 1977: Examination Report under Section 18(3)

Latest date for reply: 4 December 2003

I enclose two copies of my examination report and two copies of the new citations.

The new citations have come to my attention whilst updating the search. It is regretted that these were not cited at an earlier stage.

By the above date you should either file amendments to meet the objections in the enclosed report or make observations on them. If you do not, the application may be refused.

You should note that the normal unextended period allowed for complying fully with the requirements of the Act will end on 4 June 2004, that is 12 months after the date of this letter.

Yours faithfully

David McWhirter
Examiner

Your ref:	1999P04839/GB/R76/MM/cs	**Examiner:**	David McWhirter
Application No:	GB 0007143.1	**Tel:**	01633 813660
Applicant:	Roke Manor Research Limited	**Date of report:**	4 June 2003
Latest date for reply:	4 December 2003	Page 1/3	

Patents Act 1977
Examination Report under Section 18(3)

Plurality of invention

1. Your claims define two separate inventions not forming a single inventive concept. The inventions are:

   a. a method, of claims 1-11, for providing synchronisation between a plurality of base stations, and
   b. a method, of claim 12, of locating a mobile station using synchronised base stations.

2. You will need to amend your claims, so that they relate to only one invention or inventive concept. You will also need to make consequential amendments to the description. You may wish to consider filing a divisional application. Any such application should normally be filed no later than 3 months before the expiry of the period for putting the present application in order.

Novelty

3. The invention as defined in claims 1-4 is not new because it has already been disclosed in each of the following documents:

"Autonomous inter base station synchronisation via a common broadcast channel" (LAGRANGE ET AL.) relevant to claims 1 & 3;
EP 0817405 A2 (NEC) see column 1 line 1 - column 4 line 21 and figures 1, 2 & 5, relevant to claims 1 & 3;
* WO 99/57826 A1 (NOKIA) see page 13 line 27 - page 16 line 34 and also figure 7, relevant to claims 1 & 2;
* EP 0954122 A (SIEMENS) see abstract and paragraphs 26-35, relevant to claim 1;
EP 0560079 A1 (TECNOMEN) see page 3 lines 23-39 and page 4 line 32 - page 5 line 25, relevant to claims 1 & 2;
WO 94/28643 (NOKIA) see abstract, page 2 line 14 - page 3 line 30 and page 8 line 30 - page 9 line 32, relevant to claim 1, 3 & 4

No amendment of your claims will be needed in respect of the documents marked * if you can show that the priority date of your invention is not later than the priority date of the relevant disclosure in that document.

[Examination Report contd.]

4. The invention as defined by claim 1 is disclosed by (LAGRANGE). The paper discloses a study of a synchronisation technique between a plurality of base stations, see abstract lines 1-2.

5. Part b) is implied by (LAGRANGE) in that only stations being within transmission range can be synchronised. Part c) is also disclosed in the abstract, lines 11-13 and Synchronisation Algorithm of section III.

6. Claim 1 merely seems to differ from (LAGRANGE) in that claim 1 does not include a weighted average to calculate the time difference for the synchronisation of the base station. It could be argued that a skilled person may simplify the calculations as much as possible effectively producing the method as described in claim 1.

7. EP 0817405 does not clearly indicate the method for synchronising base stations as in claims 1 & 3, however, the citation does disclose a method for a base station to detect TDMA transmission made by adjacent base stations and used the detected transmission timings to determine the transmit time intervals of the detecting base station so that there is no conflict with the control channel signals of the adjacent base station. Such a controlled determining and adjusting of a transmit time slot is considered to fall under the term "synchronisation".

8. The remaining documents also disclose a synchronisation method as defined in claim 1. Documents WO 99/57826 and EP 0560079 seem to disclose the invention further defined by claim 2, and the use of a random access acknowledgement in a common access channel of document WO 94/28643 implies the use of a random âccess channel and would seem to anticipate the invention of claims 1, 3 & 4.

Clarity/Support

9. The characterising feature of claim 1 seems to be section c), i.e. calculating a time difference between clock pulses from the first base station and clock pulses transmitted by other base station within transmission range. Claim 1 does not, however, contain any clear feature that indicates how these values are used for adjusting (providing) synchronisation between base stations. To avoid any obscurity in the claim the following feature could be included: "using for each respective base station the calculated respective time differences for adjusting the synchronisation between the plurality of base stations."

[Examination Report contd.]

Conflict with a corresponding European patent application

10. This application appears to be similar to your European patent application published under No EP 1206849, having the same priority date and designating GB. If patents granted on these two applications relate to the same invention, the Comptroller will in due course revoke the patent granted on the present application unless **either** you amend the present specification to remove the conflict **or** , before the date of grant of the present application under Section 25(1), you begin proceedings to surrender the European patent (UK). Of course if the GB designation is withdrawn before grant of the European patent, no action will be required under Section 73(2).

CLAIMS:

1. A method of providing synchronisation between a plurality of base stations in a telecommunications system, the telecommunications system comprising a plurality of cells, each of the plurality of cells having one of the plurality of base stations and at least one mobile station, the method comprises the steps of:

a) providing at least one channel for usage in the plurality of cells;

b) transmitting a synchronisation signal in a given one of the at least one channel, the transmission being from a first base station to those remaining base stations within the telecommunications system which are within transmission range; and

c) calculating a time difference between clock pulses from the first base station and clock pulses transmitted by other base stations within transmission range.

2. A method according to Claim 1, having the further steps of:

d) for each of the plurality of base stations, reporting the time differences calculated in step c) to a radio network controller;

e) calculating a synchronising adjustment corresponding to each base station is calculated from the reported time differences;

f) informing each base station individually of the corresponding synchronising adjustment calculated in step e); and

g) adjusting the clock pulses of each base station according to the corresponding synchronising adjustment.

3. A method according to Claim 1, having the further step of:

h) the first base station acting autonomously on the time differences calculated in step c) by adjusting the clock pulses of the first base station to minimise the time differences.

4. A method according to Claims 1, 2 or 3, wherein the given channel is a random access channel transmitted at a frequency within a band of frequencies that is provided for communications with mobile stations.

5. A method according to Claim 4, wherein the random access channel comprises a time slot per TDMA frame.

6. A method according to Claim 5, wherein the random access channel is allocated to uplink transmissions in order to initiate communications.

7. A method according to Claim 6, wherein communications are initiated by requesting a resource unit for uplink usage.

8. A method according to Claims 5, 6 or 7, having the further step of:

i) allocating the utilisation of each random access channel time slot for base station synchronisation according to a schedule.

9. A method according to any one of Claims 5,6 or 7, having the further step of:

j) using a second one of said at least one channels to silence uplink communications in the random access channel time slots to allow the transmission of synchronisation transmissions from the first base station to other base stations.

10. A method according to Claim 9, wherein the second channel is the broadcast control channel.

11. A method according to any one Claims 4 to 10, wherein the random access channel time slot used is always contained in a fixed numbered frame within a plurality of multi-frames in order to synchronise the plurality of base stations over multi-frames.

12. A method of locating a mobile station within a telecommunications cell forming part of a telecommunications system, the telecommunications cell comprising a base station and at least one mobile station, the method comprising the steps of:

determining the location of at least three base stations;

scheduling synchronisation measurements for each of the base stations utilising a random access channel;

transmitting a signal from the mobile station;

receiving the transmitted signal at each of the three base stations;

comparing the received signals with timing signals in each of the base stations; and

using the comparison at each base station to determine the location of the mobile station.

13. A method of providing synchronisation between a plurality of base stations in a telecommunications system, the method substantially as hereinbefore described with reference to the accompanying drawings.

14. A method of locating a mobile station within a telecommunications cell forming part of a telecommunications system, substantially as hereinbefore described with reference to the accompanying drawings.